PROCEEDINGS

OF

THE ENGINEERS' CLUB

OF

PHILADELPHIA

VOLUME XXVI

EDITED BY THE PUBLICATION COMMITTEE

PHILADELPHIA
THE ENGINEERS' CLUB OF PHILADELPHIA
1909

INDEX—VOLUME XXVI

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THE ENGINEERS' CLUB

OF PHILADELPHIA.

ORGANIZED DECEMBER 17, 1877. INCORPORATED JUNE 9, 1892.

Vol. XXVI. JANUARY, 1909. No. 1

PAPER NO. 1063.

A CALIBRATED SPEED RECORDER.

A. B. STITZER.

(Active Member.)

Read September 19, 1908.

THE successful solution of many of the problems of train movement, and the actual performance of railway motors in service, depend upon the accuracy with which is recorded the energy absorbed by the car or train for every instant during the test.

Ammeters, voltmeters, and wattmeters, making a continuous graphic record on a time basis, have been on the market for several years and have reached that stage in their development where they have a fair degree of reliability and accuracy.

A space-time meter has not become a commercial product; in fact, there is no demand for one, as it is more desirable to measure speed time, and the space-time graph can readily be obtained from a speed-time graph by integration.

Several speed recorders have been placed on the market by various manufacturers, each of which has been produced for a special service; such is the Boyer speed recorder, whose action depends upon the pressure produced by a small rotary pump acting on a piston in opposition to two coil springs. This instrument has been extensively used in the past for recording the speed of steam railway trains. The inertia of the moving parts prohibits its use in electric traction work, owing to the rapid acceleration and retardation used in electric train movement.

Then there is the Niagara speed recorder, the theory of which is based upon the action of centrifugal force. The working element employed is mercury, and the recording pen is attached to a float, resting on the surface of the mercury. When rotation takes place, the mercury is forced up the side chambers of the instrument, by the action of centrifugal force, diminishing the volume of the mercury in the center chamber, causing the float to drop, or vice versa, as the speed decreases. This instrument is adapted for recording small variations in speed, above or below a fixed value. It cannot be made with an evenly divided scale, such as is desirable for recording speeds varying from zero to a maximum value, and is inaccurate in values 80 per cent. below its maximum indication.

Inasmuch as there is not on the market a speed recorder adapted for use in electric traction work, the following described method was devised to record the speed of a moving train accurately on an evenly divided scale, making a record which can be read without a correcting factor. The action of this speed recorder depends upon the measurement of the voltage induced in an armature revolved in a constant magnetic field, making the proper corrections for the current taken by the recording meter. The meter does not have to be installed on a car for calibration, nor does the diameter of the car-wheels make any difference, as a change in the diameter of the wheels simply necessitates a change in the resistance in series with the recording meter.

Theory.

If an armature is revolved in a constant magnetic field, the induced volts are directly proportional to the revolutions per minute. Now, if the revolutions per minute are plotted as abscissæ and the induced volts as ordinates, the result will be a straight line which may be represented by the equation:

$$\frac{X}{Y} = k \qquad \text{(Equation 1)}$$

where $X = R =$ Revolutions per minute.
$Y = E =$ Induced volts

and $$k = \frac{R}{E} = \text{a constant} \qquad \text{(Equation 2)}$$

$\frac{X}{Y} = \frac{R}{E}$ is the equation of a straight line passing through the origin and making an angle with the X axis whose tangent is equal to the constant $\frac{R}{E}$.

If the terminals of the armature are connected to a high torque

recording meter, which requires an appreciable amount of current, say c amperes, for a full scale deflection, the volts across the terminals of the armature would be less than the induced volts by the internal cr drop,

that is, $E - cr = V$ (Equation 3)

where E = Induced volts
V = Terminal volts
c = Current in circuit
r = Internal resistance of the generator.

Substituting in Equation 2 the value of E from Equation 3, we have:

$$\frac{X}{k} = Y = E = V + cr$$

$$X = kV + kcr = R$$

(Equation 4)

This is the equation of a straight line passing through the X axis,

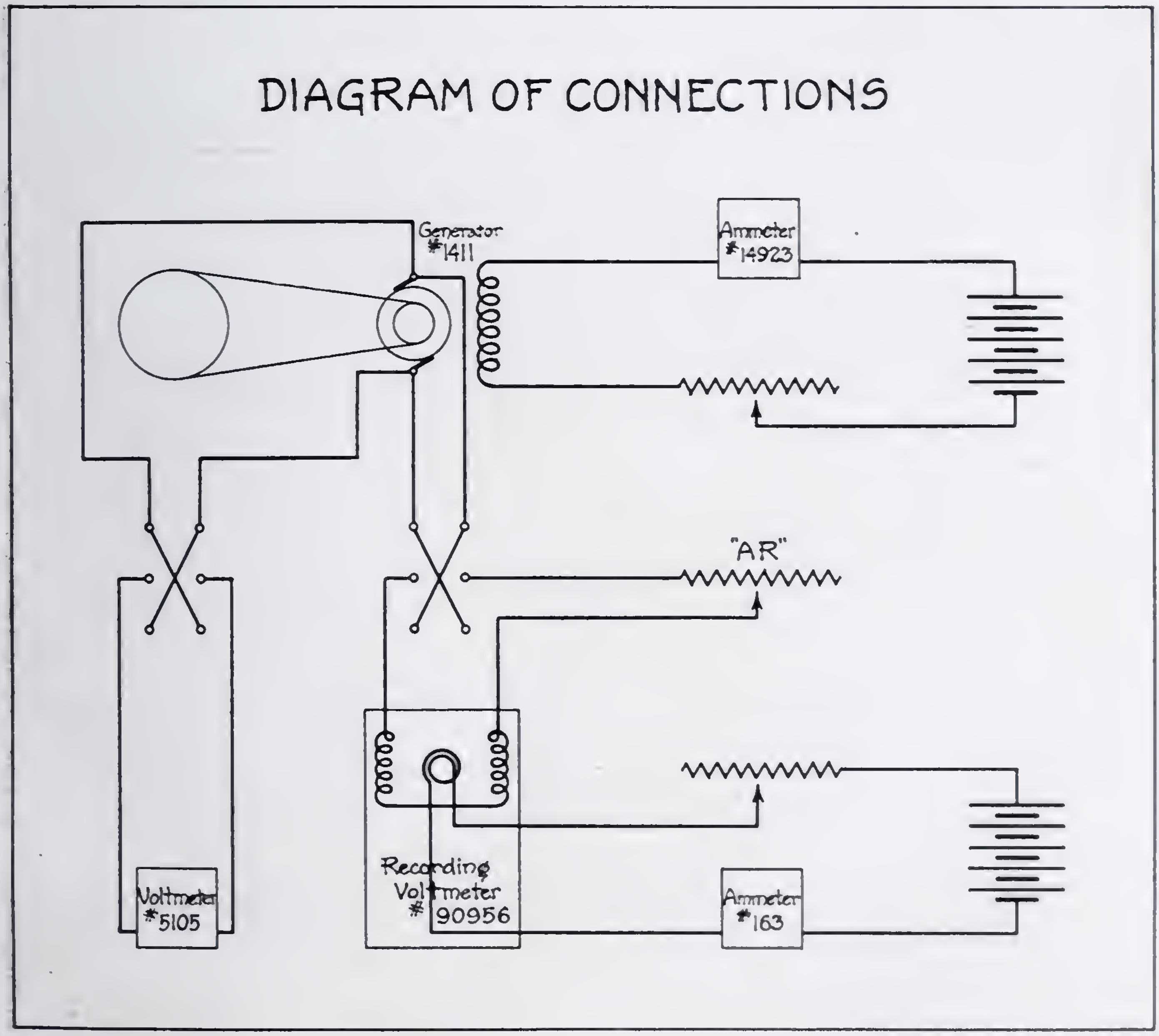


FIG. 1.

a distance kcr from the origin and parallel to the line of induced volts.

If the total resistance r_e of the external circuit be such as to give a full scale deflection of the recording meter at a certain speed of the small generator, then any deflection of the meter for speeds less than this will be directly proportional to the speed of the generator:

For $c = \frac{V}{r_e}$

where V = Terminal volts
c = Current in circuit
r_e = External resistance

and substituting in equation 4 we have:

$$kV + kV\,\frac{r}{r_e} = R$$

$$kV\,(1 + \frac{r_e}{r}) = R \qquad \text{(Equation 4a)}$$

which is the equation of a straight line passing through the origin and intersecting the locus of equation 4 at the point $V = cr_e$.

As the armature of the generator is geared to a car axle:

$$R_a = Rk_2 \qquad \text{(Equation 4b)}$$

where R_a = Revolutions of car-wheel per minute
if C = Circumference of car-wheel in inches
and S = Velocity of car in feet per second
k_2 = Gear ratio
then $\frac{R_a}{60} \times \frac{C}{12} = S$

solving for R_a we have:

$$R_a = \frac{S \times 12 \times 60}{C} \qquad \text{(Equation 5)}$$

Substituting in equation 4 the value of R from equation 4b and 5 we have:

$$R_a = Rk_2 = \frac{S \times 12 \times 60}{C} = (kV + kcr)\,k_2$$

$$\text{or } Ckk_2\,(V + cr) = S \times 12 \times 60$$

$$\text{or } C\,(V + cr) = \frac{S \times 12 \times 60}{kk_2} \qquad \text{(Equation 5a)}$$

K can be substituted for kk_2, for from equation 2 and equation 4b we have:

$$R = Ek = \frac{R_a}{k_e}$$
$$R_a = Ekk_2 = EK$$
$$K = \frac{R_a}{E} \quad \text{(Equation 5b)}$$

or K expresses the ratio of the revolution of the car axle to the induced volts of the generator.

Substituting in equation 5a the value of kk_2, we have:

$$C\ (V + cr) = \frac{S \times 12 \times 60}{K} \quad \text{(Equation 6)}$$

This is the equation of an equilateral hyperbola, the X axis of which is displaced a distance cr above the true center.

Equation 6 contains two quantities, K and cr, which under the condition (a full scale deflection of the recording meter) are constants, and three quantities, C, V, and S. The first two of these are variables, but the last (S) must have a value consistent with small c. The value of S for this particular meter had best be some multiple of fifteen, because the recording paper has fifteen divisions. We will, therefore, take S as 30, 45, and 60 feet per second. These values are such that each division of the paper will represent speeds of 2, 3, or 4 feet per second. Other values may be used if desired.

Equation 6 will thus become:

$$C\ (V + cr) = \frac{30 \times 12 \times 60}{K} \quad \text{(Equation 7)}$$

for 2 feet per second per division.

$$C\ (V + cr) = \frac{45 \times 12 \times 60}{K} \quad \text{(Equation 8)}$$

per 3 feet per second per division.

$$C\ (V + cr) = \frac{60 \times 12 \times 60}{K} \quad \text{(Equation 9)}$$

for 4 feet per second per division.

Should it be desired that the record be made in miles per hour, we have:

$$60\ R_a \times \frac{C}{5280 \times 12} = M$$

where R_a = revolutions per minute of car axle.
C = circumference of car wheel in inches.
M = velocity in miles per hour of the car.

or $$R_a = \frac{M\ 1056}{C} \quad \text{(Equation 10)}$$

Substituting in Equation 4 and 4b we have:

$$R_a = Rk_2 = (kV + kcr)\,k_2 = \frac{M\ 1056}{C}$$

Substituting K for kk_2 we have:

$$CKV + CKcr = M\ 1056$$

$$CV + Ccr = \frac{M\ 1056}{K}$$

$$C\,(V + cr) = \frac{M\ 1056}{K} \qquad \text{(Equation 11)}$$

Substituting in Equation 11 either 15, 30, 45, or 60 for M, we get an equation connecting circumference and volts for velocities of 1, 2, 3, or 4 miles per hour per division of the recording paper, according to he value of M used.

Description of Apparatus Used.

A generator is bolted to the truck framework and driven from the car axle by a Renold silent chain; ½ inch pitch, ¾ of an inch wide.

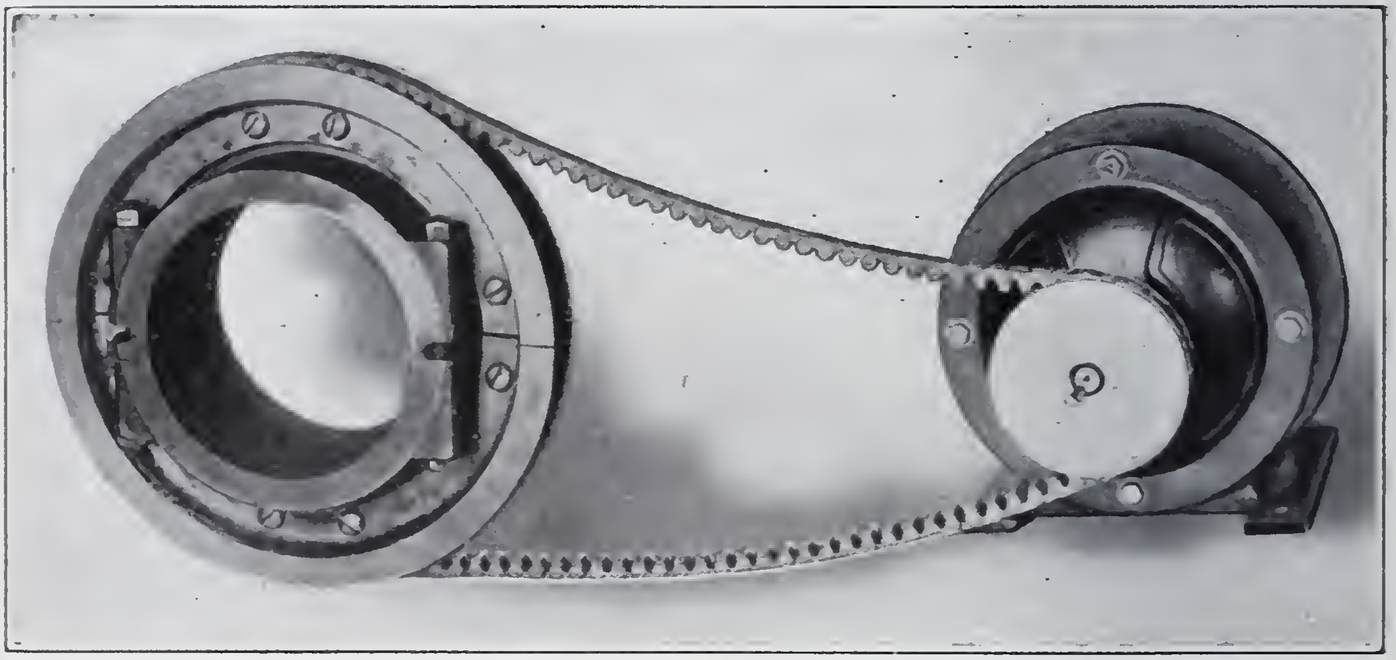


Fig. 2.

The diameter of the driver is 12.09 inches, with 76 teeth. The diameter of the pinion is 3.99 inches, with 25 teeth.

The generator was furnished by the Rossmassler-Bonine Electric Company, and is built on their No. ½ frame; the armature being wound for 110 volts at 1000 R. P. M. The winding is made up of 40 sections, each having 17 turns of No. 21 double cotton covered wire. Each

field coil is wound with 235 turns No. 14 single cotton covered wire, and the resistance of the two in series is 1.45 ohms at 28° Centigrade.

A graphic recording voltmeter as manufactured by the General Electric Company is used as the speed recorder. This instrument was designed for registering accurately, violently fluctuating voltage values. The indications are recorded upon a rapidly moving chart, thus leaving a permanent record of instantaneous values. It is constructed upon the dynamometer principle, separately excited, and the

Fig. 3.

voltage to be measured is passed through the stationary coils. This construction gives an extremely high torque, so that the pen friction is negligible, and the pointer takes a new and definite position for each change of voltage. There is no overrunning of the pointer due to the inertia of the moving parts, as the instrument is perfectly dampened.

The chart or record is driven by a spring motor, regulated by an adjustable friction device, and timed by the graduations on the driving drum. The normal rate of feed is six inches per minute.

The exact speed is indicated by two second intervals marked on the

side of the chart by a pen actuated by a magnet connected to a battery and a "chronograph attachment." The record paper comes in rolls sixty-five feet long and three and one-half inches wide, with a scale three inches wide divided into fifteen equal spaces.

The coil of this recording meter is separately excited from a small

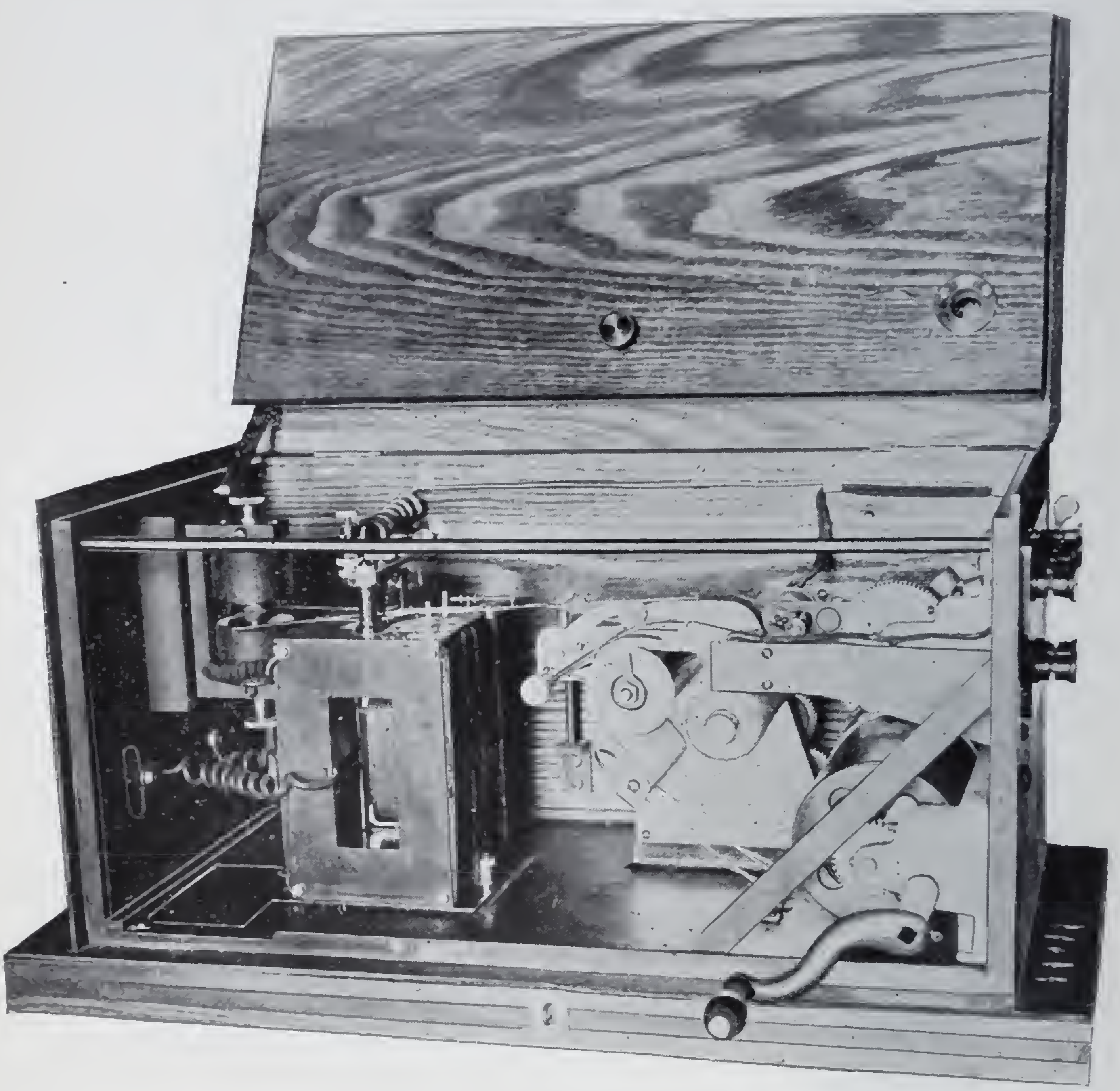


FIG. 4.

storage battery and kept at a constant value of 1.509 amperes by means of an adjustable resistance connected in series with it. The field of the generator is also separately excited, and is maintained constant at 5 amperes by means of an adjustable resistance. Two portable 5-cell, 5-plate, storage batteries are used for this work. The one having a normal discharge rate of 5 amperes was used for exciting the coil of

the recording voltmeter; the other, having a normal discharge rate of 10 amperes, was used for exciting the field of the generator.

The voltmeter was supplied with an adjustable resistance, which we will call AR, to be placed in series with the fixed coil. This resistance is made up of 16 coils, 1½ inches in diameter and 14 inches long, held in an iron frame. The collector brushes of the armature are set at the

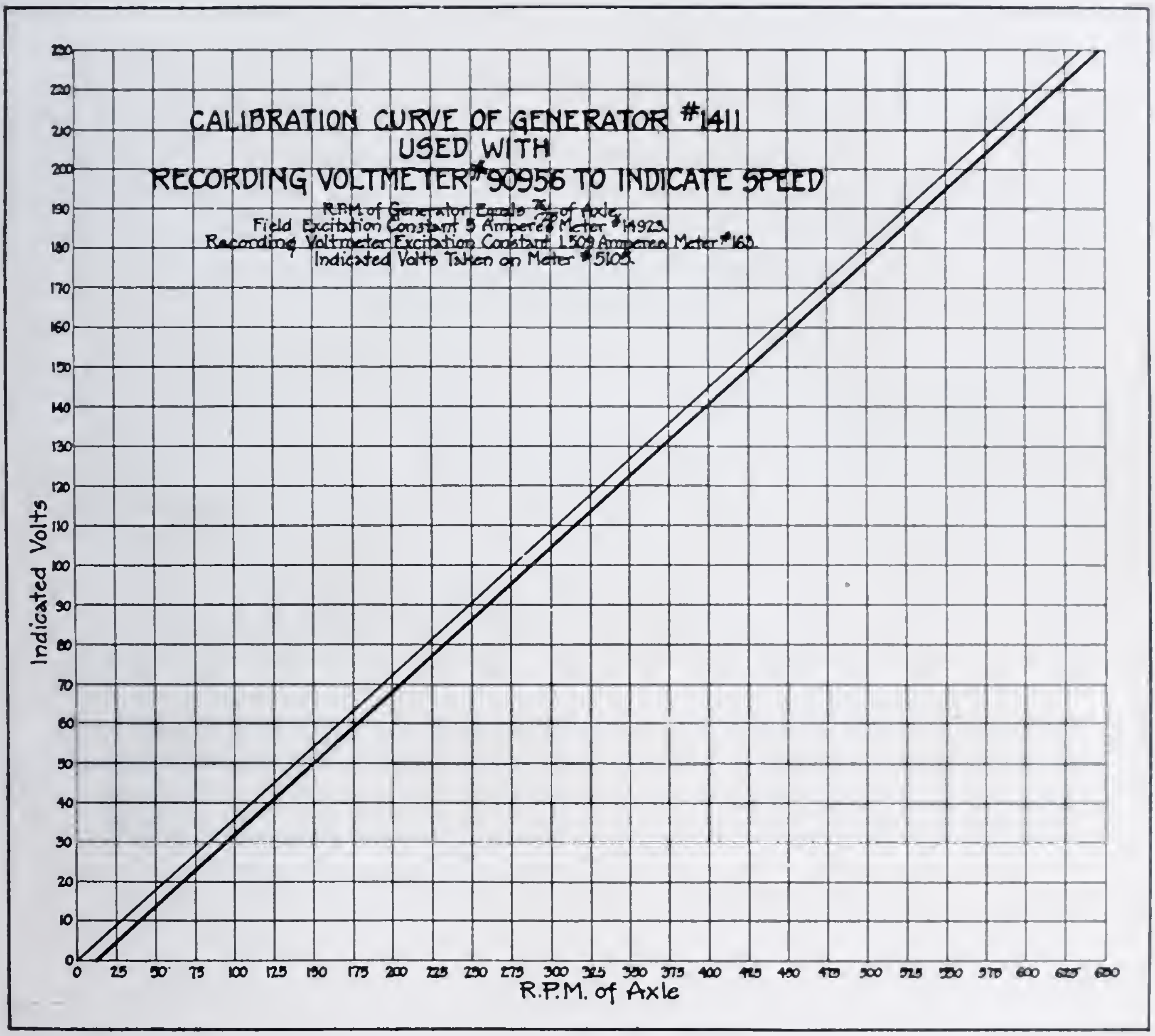


FIG. 5.

mechanical neutral, and a direct-reading, high-resistance voltmeter connected to them.

DETERMINATION OF CONSTANTS.

The fields of the generator and the recording meter are excited and the armature driven by the chain from the large sprocket, which is attached to a lathe or a variable speed motor.

The resistance AR in series with the meter is varied until a full scale deflection is obtained on the recording meter.

The speed R of the large sprocket and the voltage V as indicated on the high-resistance voltmeter are noted. The recording meter is then disconnected and the open circuit voltage E of the generator taken.

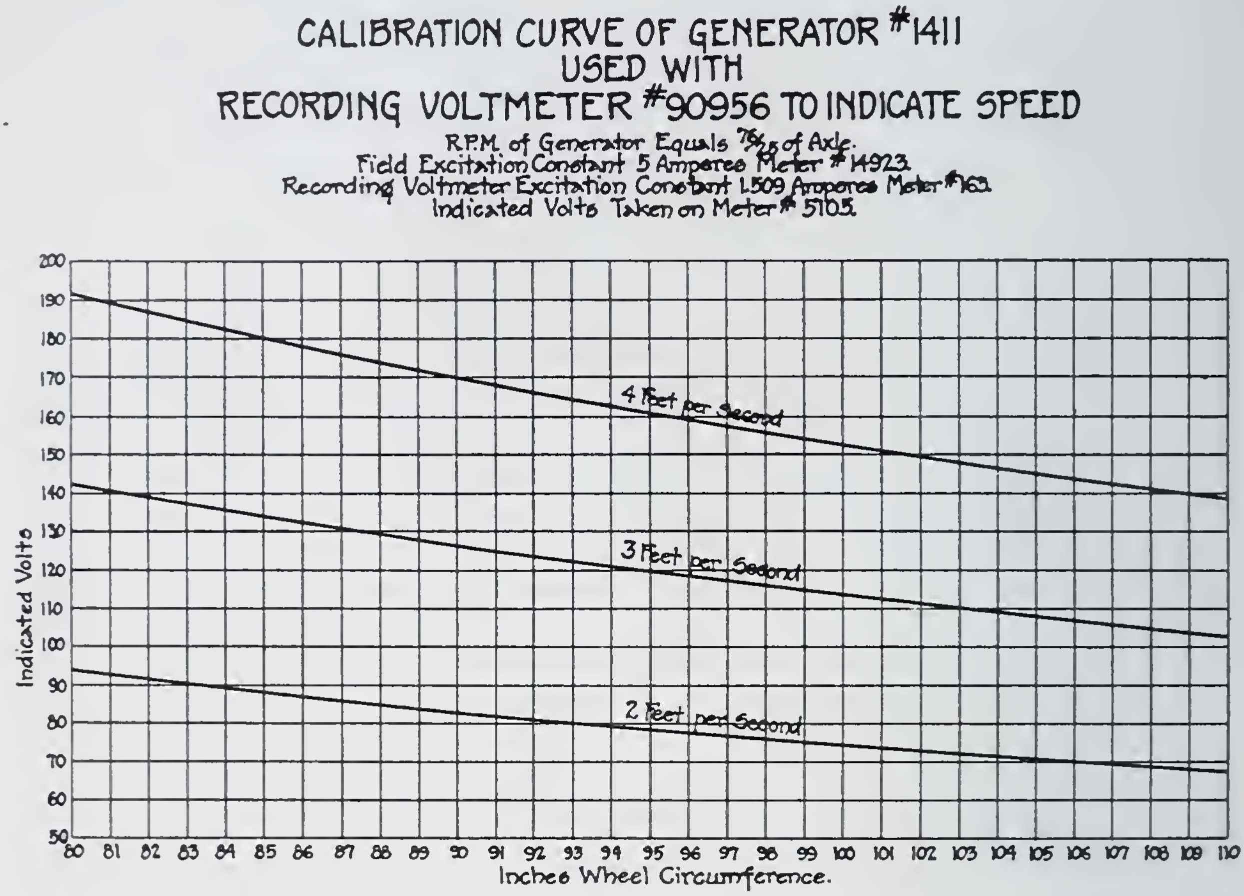


FIG. 6.

We then have from equation 3:

$$E - V = cr$$

and from equation 2:

$$\frac{R}{E} = k$$

Several readings may be taken by changing the speed of the large sprocket and the resistance AR, and the mean values used.

A glance at equations 7, 8, and 9 will show that with k and cr known

the locus of each of these equations can be plotted by assuming values for C or V and solving for the other.

These curves should be plotted on a large sheet of cross-section paper, taking the values of C (circumference) as abscissæ and the values of V (terminal volts) as ordinates.

This completes all the necessary preliminary calibration.

To use the apparatus it is only necessary to install it on a car and adjust the resistance AR until a full scale deflection of the recording meter is obtained while the voltage, corresponding to the scale and the circumference of the car wheel, is impressed across the terminals of the armature.

The terminals, during this procedure, are insulated from the armature by sliding strips of mica under the brushes.

When AR is adjusted, the resistance of the external circuit is fixed and the deflection of the recording meter pen will be directly proportional to the speed of the car, as previously shown.

Inasmuch as the maximum deflection and each division thereof represents a definite speed, we have a means of recording accurately on an evenly divided scale, on a time basis, the speed of a car or train.

PAPER NO. 1064.

THE DEVELOPMENT OF THE DOWNFLOW BOILER.

J. C. PARKER.

(Active Member.)

Read October 17, 1908.

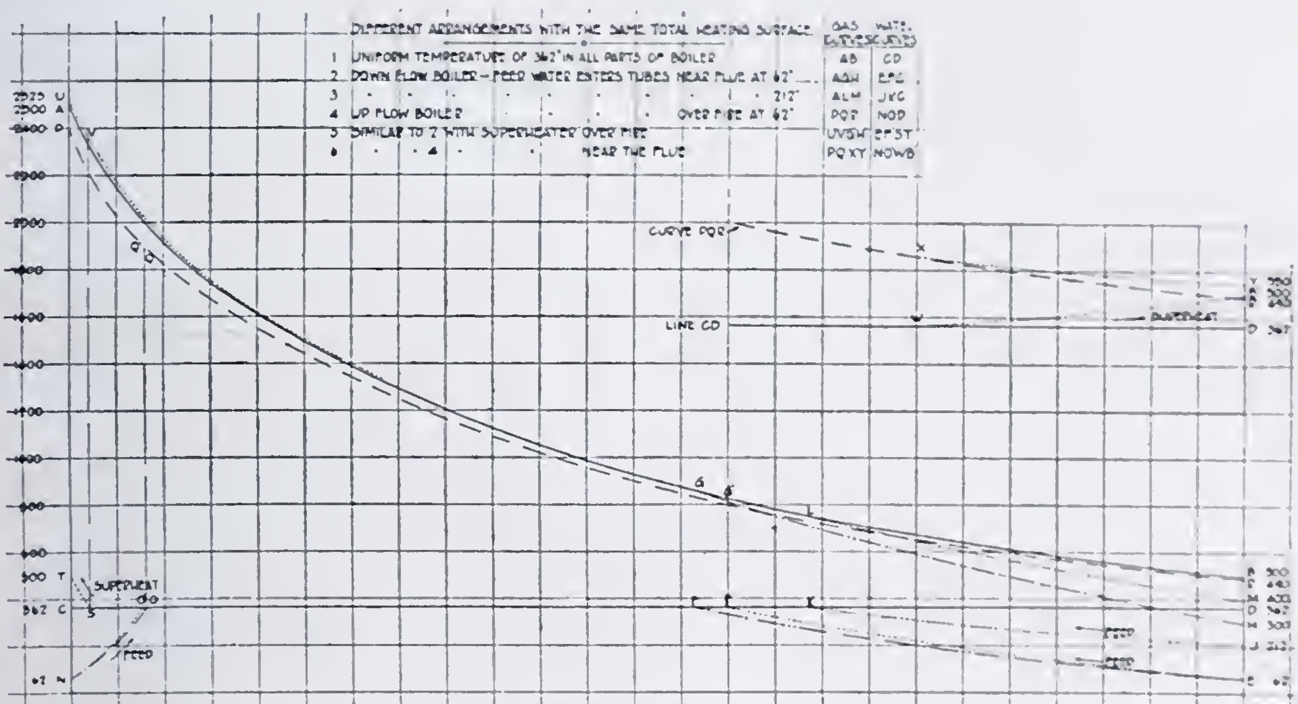
PAPERS describing the downflow type of steam generator were presented before the Engineers' Club of Philadelphia seven years ago by Mr. Henry G. Morris and the author.* This boiler was then in the early stages of development. Considerable experimental work had been done and one 175 H.P. unit had been in service one year at Roach's shipyard in Chester, Pa. Since that time the "downflow" has been divided into two, three, and even four stages, so that the boiler as now built (excepting very small units) does not correspond with the description then given. Many thousands of horse-power have been installed throughout the country and the boiler has proved its ability to operate under adverse and widely varying conditions. It has also proved itself to be exceptionally safe, as there is no record of personal injury, loss of life, or damage to property.

The author's connection with the boiler problem came about in a rather curious way. Experiences with gasoline launches in San Francisco Bay in the early nineties led him to attempt some improvements in gas engines, and wanting means to keep an engine in motion for experimental purposes, he constructed a steam-generating coil operated with a gas-burner. The coil consisted of 50 feet of $\frac{3}{8}$-inch copper pipe into which the water was introduced at the top end from a small tank, and from which the steam discharged at the bottom end next to the fire through a direct upcast to the steam space in the tank. The idea, of course, was to absorb more heat from the escaping gases through the agency of the cooler water coming into the top end of the coil. This device operated satisfactorily until an air-blast was attached to the burner, when the flow was reversed and would not resume its former course until the burner was turned down very much below what the coil would ordinarily operate at with safety. A check-valve was then inserted between the tank and inlet end of the coil to prevent

* Proceedings, vol. xviii, No. 3.

reversing the flow, and thereafter the coil was operated to the limit of the burner without any trouble. Experiments were then made with glass models, and it was demonstrated that glass tubes would stand more heat with this method of circulation than with the common method of inclining the tubes, and in the same model the bottom tubes withstood the fire better when the coil was supplied with water at the cold end than when it was supplied at the hot end.

The heat diagram (Fig. 1) compares three types of boilers: the uniform temperature boiler, the downflow boiler with cold feed water entering the tubes near the flue, and the upflow boiler of the early Belleville type with cold feed water entering the tubes directly over the fire.



HEAT DIAGRAM

FIG. 1.

The effect of superheaters and of varying temperatures of feed water is shown. Each arrangement has the same total amount of heating surface. Equal amounts of fuel are consumed in each case, so that the power generated is directly proportional to the efficiency of boiler and furnace.

Temperature in degrees Fahrenheit is indicated by the vertical scale. Total heating surface is represented by the length of the diagram. The surface at the extreme left is directly over the fire and in contact with the hottest gases.

Line C D indicates the pressure boiling-point, 362° F. This line is horizontal, indicating that the entire boiler surface is used for evapor-

ating. Curve A B indicates the progressive drop in temperature of the gases from the initial combustion temperature (2500°) to 500° at point of exit.

Arrangement No. 2 is the downflow boiler. Feed water at 62° enters near the flue. Line E F shows its rise in temperature to the pressure boiling-point, 362° F. This represents about 24 per cent. of the heat absorbed by the boiler and requires nearly one-half of the total surface. The continuing line F C represents the change from water to steam at constant temperature. The temperature of the gases from A to G is exactly the same as for the uniform temperature boiler. Beyond the latter point the lower temperature in the economiser element of the downflow boiler causes a more rapid absorption of heat, and the gas temperature follows the line G H to a final temperature of 300° F. This is 238° higher than the feed temperature. The absorption of heat is, therefore, about 75 per cent. greater than in the corresponding part of the former boiler, which has only 138° difference in temperature.

The downflow boiler thus makes it possible to reduce the flue gases considerably below the temperature of the steam generated. About 10 per cent. gain in economy and power is produced by reducing the gases 200° below the flue temperature of the simple boiler.

If the feed water comes from a heater at 212°, the downflow boiler will still show a substantial gain. Line J K shows the rise in temperature from 212° to the boiling-point. This represents 15 per cent. of the total heat absorbed by the boiler and about 37 per cent. of surface is utilized. Evaporation takes place along the line K C. The corresponding gas temperatures follow the line A L M and pass to the stack at 400°.

Arrangement No. 4 shows the upflow boiler, with water at 62° directly over the fire. The immediate effect is to lower the combustion temperature and thereby cause a loss. The initial temperature is taken at 2400°. The drop in temperature from P to Q is greater than in the corresponding portion of the curve A B, owing to the greater temperature difference of boiler and gases. N O represents the rise in temperature of feed water, requiring only about 6 per cent. of surface. The continuing line O D with 94 per cent. of surface completes the evaporation. The gas temperature curve Q R is only 10° below the curve A B at the point of exit. This is insufficient to compensate for the initial loss and the boiler is less efficient than the boiler of uniform temperature.

Arrangement No. 5 considers the downflow boiler with a small portion of its surface directly over the fire operating as superheating surface. Feed water at 62° is heated along the line E F^1. Evaporation takes place from F^1 to S. Less than 2 per cent. of surface is sufficient to superheat the steam to 500° F. along the line S. T. In this arrangement the high temperature of the surface directly over the fire raises the initial temperature to U, which improves combustion.

The flow of water and steam is opposite to the gases, and it is to be noted that as fast as the heat transfers from the latter to the former it is carried back toward the point where it was originally generated. This is an application of the regenerative principle, which has been profitably used in many of the arts, and any departure from it is bound to result in loss.

A superheater over the fire adds slightly to the efficiency, having an effect opposite to the introduction of feed water at that point.

From this it may be inferred that a superheater near the flue, without additional surface, will result in a loss of efficiency. This is the case, as shown in arrangement No. 6. Heating and evaporation take place respectively along the lines N O^1 and O^1 W. The corresponding gas temperatures are on the lines P Q^1 and Q^1 X. Superheating takes place on the line W B^1 to a final temperature of 500° F., and nearly 30 per cent. of surface is required. The constantly rising steam temperature rapidly reduces the temperature difference between the superheater and the gases, so that much less heat is absorbed than in a uniform temperature boiler. The gases are cooled from X to Y and leave at 550°. This higher flue temperature represents a loss of nearly 3 per cent. for the superheater, in addition to the initial loss caused by the feed water. The upflow type is thus seen to be considerably the least efficient one under discussion, and a competitive test of such a boiler with its opposite, the downflow boiler, would probably show from 15 to 20 per cent. better economy for the latter.

To get increased economy the feed water must be introduced where it will not affect combustion. The gain is a maximum near the cool end of the boiler. The use of a portion of the total surface for superheating at the cool end or in an intermediate position must lessen economy. Superheating at the hot end increases it.

The circulation diagram (Fig. 2) shows an ideal arrangement based on the requirements of the heat diagram. The water enters the top end of the coil near the flue, where it cools the waste gases to the lowest point, and flowing toward hotter gases soon reaches the pressure

boiling-point. Steam bubbles appear in increasing numbers as the fire is approached, and the flowing water is gradually changed to flowing steam, which is forced along by the gravity head of water above it and is discharged through the upcast into the drum. The flow, of course, will continue as long as the fire is kept up and a water level maintained in the drum. In practice, superheating cannot be accomplished as shown, because if the coil were made long enough to completely evaporate the water, the superheat starting-point would move back and forth in the tubes with every change in the fire and the temperature would fluctuate widely. It has also been found desirable

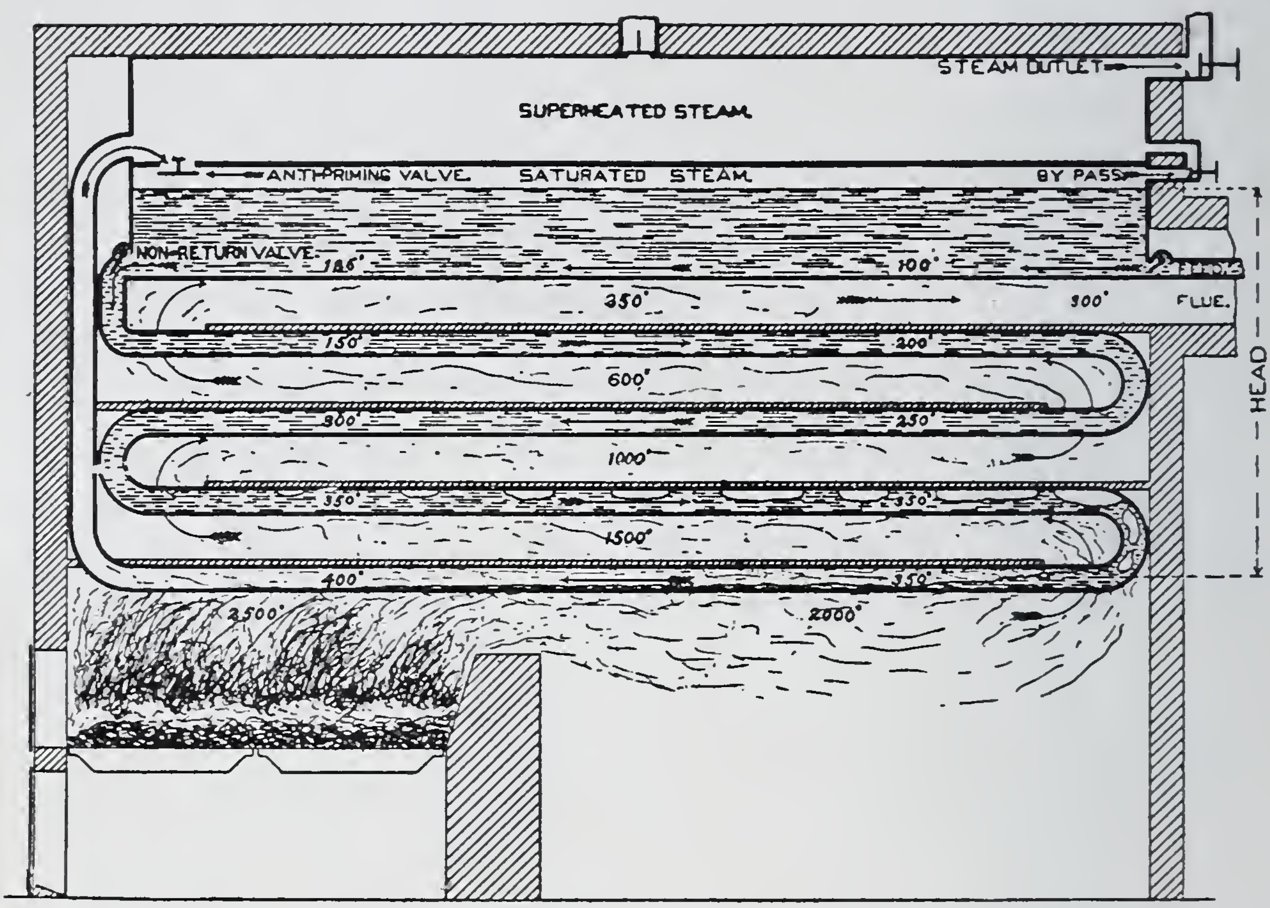


Fig. 2.

to separate the feed heating and evaporating into two downflow stages, because at times the coil is required to run with the feed shut off and water entering the top end at the pressure boiling-point. The principles illustrated by the heat and circulation diagrams have not, however, been departed from.

Application was made for a patent on the downflow boiler in 1897, and the principal reference from the patent office was the Belleville boiler, but as the flow was upward in the coils (which Belleville termed "elements"), the reference did not hold. The fact that similar elements are used in the Belleville boiler, and that the flow is exactly

the reverse of this, makes it of interest. The Belleville boiler has had a very remarkable history. M. Julian Belleville began work on the boiler problem in 1850, and patented in France an "instantaneous steaming boiler," which was a coil extending horizontally with vertical tubes, the water being forced in at the cold end with a feed pump. In 1856 he tried coils with horizontal tubes, with the water forced in at the hot end, in the dispatch boat "Biche" of the French navy. These failed, as did those of the "Argus" and "Sainte Barbe" in 1861. He seems to have worked continuously on the problem, and as late as 1872 (quoting from "Marine Boilers," by Bertin and Robertson) we find him using the sound portions of 18 boilers which were tried in the yacht "Hirondelle" to construct nine new ones. These were again unsatisfactory, and M. Belleville is quoted as being "less discouraged than ever." His extraordinary persistence was crowned with success in 1878, after twenty-eight years' continuous endeavor.

When the writer took up the boiler problem, the Belleville boiler had just been adopted in the British navy, and two cruisers (the "Powerful" and "Terrible") had been fitted with them. On this account more attention was being given the boiler question in Europe than in this country, and the British engineering world was particularly worked up over the adoption and merits of the French boiler. About one million H.P. were installed in the British navy, but by 1900 the opposition became so strong as to force a Parliamentary Commission, which finally condemned the boiler for use in new ships. The boiler, however, has done remarkably well for twenty years in many ships.

Belleville's failure of 1856 was not on account of putting the water in at the cold end and taking the steam off at the hot end of his elements, but because he had no dependable flow independent of his feed pump, and it was not until he added a downtake pipe to form a *complete circuit* in his 1878 model that he was at all successful.

Comparing the downflow with the upflow elements of Belleville, the downflow limit of length with 4-inch tubes is about 400 feet, against 100 feet for the upflow. The reason the downflow elements can be made so much longer than the upflow is because most of the steam is made in the lower tubes, and it escapes more readily through the upcast from the bottom end than through the entire coil and bends, the friction being very much less in the downflow than in the upflow boiler. As regards the protection of the bottom tubes, there is no advantage in putting the water in at the hot end, because steam is made there in either case, and the flow is very much slower. With the

downflow type there is no difficulty in supplying the bottom tubes with sufficient water through the elements, and the fact that elements four times as long operate safely is indicative of the superiority of the downflow method.

The later Belleville boilers have an economiser above the steam drum, the flow being upward, as in the boiler proper, but without the circulation.

Inclining the tubes is the most common method of producing circulation in water tube boilers. The steam flows up the inclined tubes and headers and finds its way through the water to the steam space. The water is circulated so many times that the temperature is practically the same through the apparatus. In fact, an even temperature is necessary to prevent straining the inflexible structure from unequal expansion. It is not possible, therefore, to meet the conditions of the heat diagram without the use of a separate economiser. Builders of this type of boiler attempted some years ago to utilize the triangular space under the drum for economiser tubes, but the space does not lend itself to a convenient arrangement and is difficult of access to remove dust and scale. Rapid pitting also developed and the plan was abandoned. Inclined tube circulation is subject to reactions, both from changes in the fire and pressure drops which cause frequent overheating of the tubes, as is evidenced by the fact that they are always found more or less sprung after continued operation. Occasionally the tubes open up and fatal accidents occur, such as happened recently on the U. S. battleship "Tennessee." When a tube lets go, the water has direct access to both ends, and enormous energy is let loose, so that the men have little chance to get away, especially in contracted fire-rooms. In the past ten years in Philadelphia alone, this type of boiler has been responsible for more than one death each year.

A model (Fig. 3) was constructed by the author in San Francisco. It consists of 21 copper and 3 glass tubes $\frac{1}{4}$-inch inside by 10 inches long, formed into a single coil. The tubes are bent into U-shaped pairs, the two ends being soldered into the tube sheet, to which is bolted a cover-plate with return bends cored in the proper position to direct the flow from one pair of tubes to the next, and downward from row to row. The eighth, sixteenth, and twenty-fourth tubes are Scotch water-gage glasses, held in asbestos-covered stuffing-boxes. The upcast is glass and also the neck for draining the steam drum into the water drum. The anti-priming valve is located in this neck and

prevents lifting the water during pressure drops. A rear valved connection acts as a by-pass to prevent excessive difference in pressure between the drums. There is a swing check valve in the connection between the water drum and the coil. Including connections, upcasts,

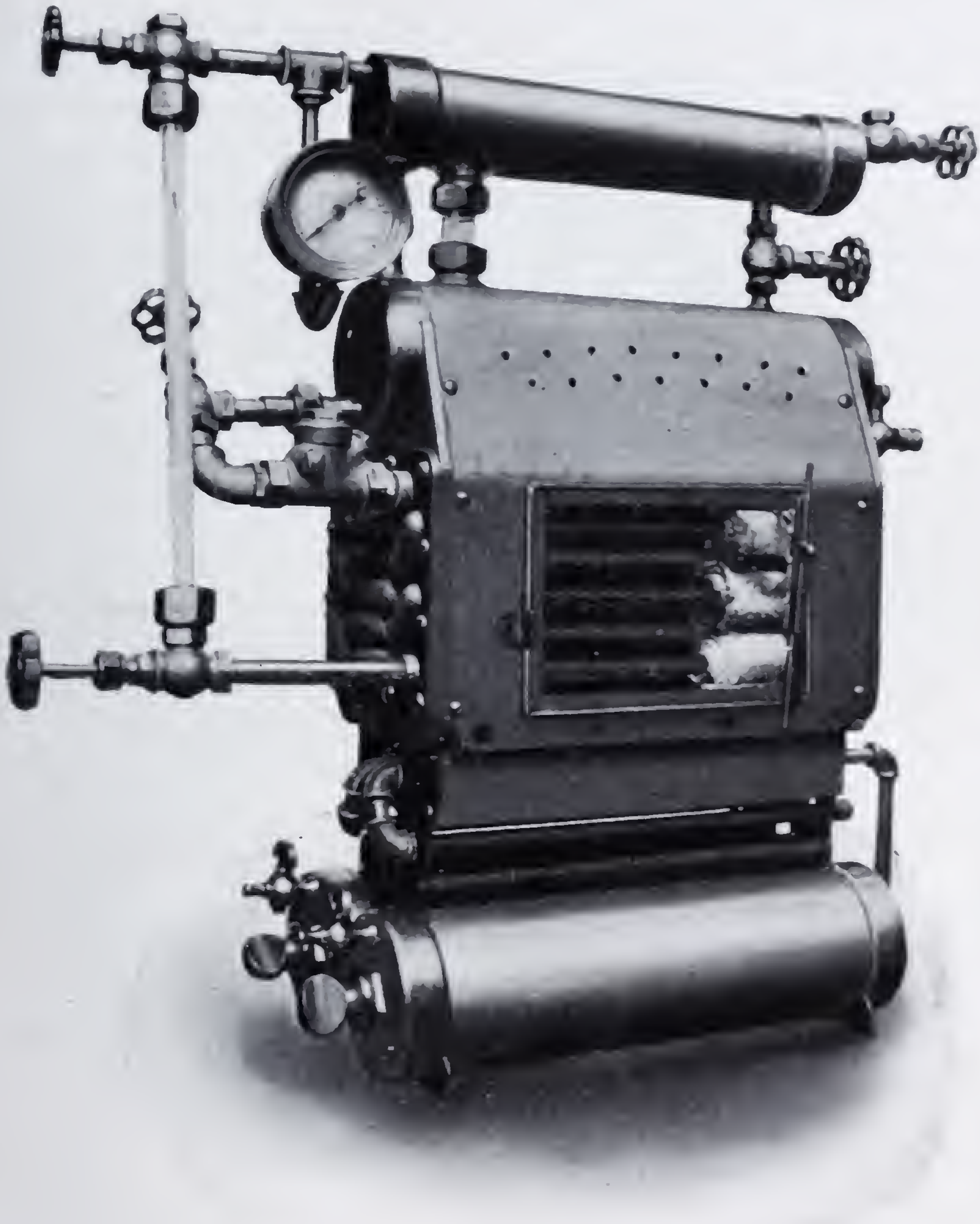


Fig. 3.

and bends, the coil is about 25 feet long. When the water drum is filled, the water runs down into the coil and finds the same level in the upcast as in the drum. In starting, there is no circulation until some steam is made in the tubes. The expansion of the steam quickly

drives the water out of the upcast, when the unbalanced head of water in the drum and tubes causes a rapid downflow. The model has been operated by the upflow method and developed a considerable water hammer, and the glasses would not withstand the six oil burners, while with the downflow the glasses can be relied on.

The model was exhibited before a great many engineers and boiler builders. The idea was general that it was against the laws of nature for the steam to go down, and that if a boiler were built the steam would become pocketed in the tubes. Another idea was that the bottom tubes would burn out on account of the flow through them being mainly steam. Still another criticism was that the operation of the boiler depended on check-valves, which would scale up quickly and stick, causing the flow to be reversed and the tubes to be burned out.

Failing to interest the boiler builders and engineers, the writer located in Philadelphia ten years ago and made arrangements to build an experimental boiler at Roach's shipyard in Chester. It was experimented with for about six months, and was finally tested by Dr. H. W. Spangler, Professor of Mechanical Engineering at the University of Pennsylvania. There were three 10-inch O.D. drums 3 feet long, 160 1-foot O.D. by 3 feet tubes, and 36 fire-box tubes $1\frac{1}{2}$ and $1\frac{3}{4}$ inches O.D. by 3 feet long. The grate was 21 by 34 inches—5 square feet. The headers were similar to the model. They consisted in a pair of cored tube sheets with cored cover-plates which when bolted to the tube sheets formed return bends, the idea being that the one large outside joint would obviate a lot of inside ones, a steam-tight joint not being essential between the inside ribs.

Experience with this boiler, however, led to the development of the two-tube junction box and the use of larger tubes. The question of hand-hole joints was an important matter. Investigation showed that outside ground-joints do not remain tight. An inside oblong plate covering two tube ends would weaken the box. Inside oval plates for each tube are used, but inside joints with gaskets are difficult to clean and require a large amount of work and care; besides the gaskets add to the cost. These joints also get leaky from heating and cooling. It occurred to the writer to design a boiler so that the tubes could be withdrawn between the headers. The hand-hole then need not be larger than the inside of the tube, and a circular cover can be slipped through the tube-hole and seated in the smaller hand-hole. The great advantage of a circular cover lies in the fact that it can be turned with

a key and ground to its seat. The oval cover cannot be turned, and the seat must be scraped clean, while the circular cover cleans itself and its seat at once. The main objection was that the covers could not be removed without taking off the box. Experience has developed no

FIG. 4.

need for their removal, and it is a distinct advantage not to have the covers knocked about.

Figs. 4 and 5 show the design of the junction box. It consists of two circular parts, each having a tube-hole and hand-hole opposite, and joined by a circular mid-section with a sufficiently large core to allow

FIG. 5.

passing the hand-hole covers from side to side. The box is for 4-inch O.D. tubes spaced 6-inch centers, giving one inch of metal around the tube to resist the expander. The flanges are double, with ribs between to prevent locking, and are octagon-shaped to fit well together. The tube seat is 1 inch long, with a slight taper on the outside to facilitate

entering the tubes. The hand-hole seat is conical and the cover has a ball face. These boxes have been tested up to 2700 pounds per square inch without developing any weakness. Their greatest element of strength is in the design and the fact that they only connect two tubes. The coil construction also frees them from the expansive strains to which other boiler headers are subjected. Malleable iron has proved entirely satisfactory, both in this and in the Belleville boiler, which carries 300 pounds pressure. Steel castings were formerly used in the Belleville, but have been abandoned in favor of malleable iron. The British commission made no criticism of the Belleville junction boxes, and no accident was attributed to their use, but the leakage from the oval inside packed hand-hole joints was ascribed as the cause of the large loss of fresh feed water aboard ships.

The first service boiler has served the boiler and blacksmith shops at Roach's shipyard in Chester for about eight years. This boiler was described in Mr. Morris' paper seven years ago. It has eight elements, each containing fifteen 3-inch tubes 18 feet long, and is rated at 175 H.P. It has 1750 square feet of heating surface and 36 square feet of grate surface. Dr. H. W. Spangler ran six tests on this boiler, averaging 11.88 pounds of steam per pound of combustible, with Georges Creek coal, at 140 H.P. Afterward, with the aid of a series of steam jets in the flue, giving $\frac{3}{4}$-inch draft, the boiler was forced up to 265 H.P. with about 5 per cent. drop in economy. A standard 150 H.P. return tubular boiler alongside, tested with the same coal and under the same conditions, gave 10.97 pounds of steam per pound of combustible, a difference of 8 per cent.

The boiler developed a peculiarity in scaling: all the tubes above the bottom row remained perfectly clean and black. The brass check-valves also remained bright. Hard scale formed in the bottom row of tubes, but kept cracking off in small pieces, which were carried up and deposited in the drum. Large quantities of scale are discharged from the tubes in this way and are found heaped up in the drums at each cleaning; 1500 pounds have been removed from the drums of a 700 H.P. boiler after a two months' run.

It has been found, however, that with bad water the scale gains, and, if allowed to reach undue thickness, it may crack off in such large pieces as to clog an element and cause bending of the tubes. It is now the practice to put a turbine cleaner through such tubes as require it. The flexibility of the boiler allows a steam cleaner to be used without injury to the joints, and the self-cleaning feature makes the balance of the scale easy to remove.

The valves remain clean indefinitely with some waters, and need reasonably frequent cleaning with others. They may be removed and replaced without emptying the elements, and it is easy to keep them in condition to insure against trouble. Elements have run for extended periods without the valves, but while trouble does not always follow neglect to keep them in good condition, it usually indicates such neglect.

The disadvantage in height from using two drums, one above the other, led to the design of the diaphragm drum (Fig. 6). The first

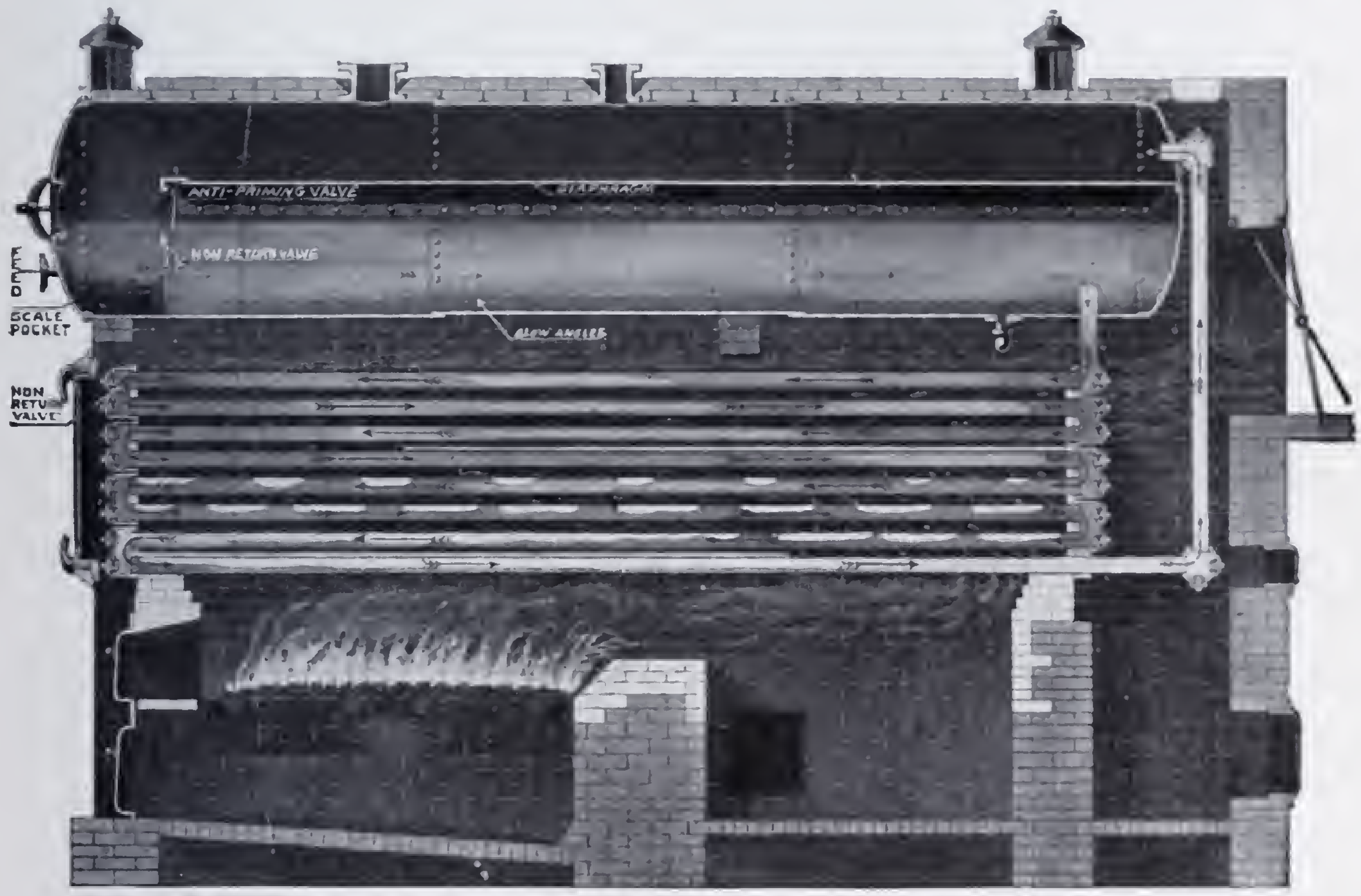


Fig. 6.

boiler with this type of drum was installed at the Michigan College of Mines by Prof. O. P. Hood, who made numerous interesting experiments on the circulation and presented a paper on the subject before the Copper Country Engineering Society in 1902. A drum of liberal capacity is used and a horizontal plate diaphragm forms separate steam- and water-chambers. The diaphragm is curved upward for strength and to give more room in the water-chamber for cleaning. A scale pocket is formed at the front end, between the drumhead and diaphragm head. A 12 by 16 inch manhole with anti-prime valving

prevents lifting the water upon drops in pressure and maintains the flow into the elements. A small by-pass serves to prevent excessive difference in pressure and insures equalization with sufficient rapidity to prevent forcing water over into the steam-chamber. The flow in the tubes is thus maintained independent of pressure drops. The diaphragm also serves to prevent the rapid discharge from the upcasts from stirring up the water surface and making spray or wet steam.

The water discharges from the elements, flows along the top of the diaphragm and into the scale pocket, where it deposits the heavier particles of scale. It then passes through the anti-priming valve and flows slowly toward the element inlets at the rear end. These project 6 to 8 inches above the bottom of the drum, thus forming a mud-pan in the segment below their level. As the steam does not rise through the water, the absence of ebullition makes the water-chamber an ideal settling reservoir, much larger in capacity than the average mud drum. The heavy mud is found on the front ring and tapers off until the lightest is found on the rear ring. The blow-off opening was at first placed near the front, where the heaviest mud is found, and had a suction arrangement toward the rear. It has been found better, however, to place the blow opening just in front of the element inlets to intercept the lighter sediment. The blow-angle or suction pipe with holes in the bottom is extended toward the front to draw the mud into the blow-off pipe. The suction must not be too much distributed, however, or the efficiency of the blow-off will be reduced.

Fig. 6 shows a vertical element type of boiler, in which each vertical row of tubes forms an independent steaming element. A number of boilers were built with this type of elements and were operated for two or three years, but owing to the sagging of the tubes the elements were finally rearranged by removing one-half the junction boxes and reforming into the standard double element type. Vertical elements with small tubes show the same characteristic sagging. At first sight there was no apparent reason why the downflow should not operate as well in the vertical as in the double element. The reason lies in the fact that the latter has two bottom tubes exposed to the fire, which prevents any trapping action. In the downflow boiler it is necessary to apply the heat first to the bottom tubes to start the flow in the upcasts and keep it going, and the single-bottom tube of the vertical element does not do this so efficiently as the two-bottom tubes of the double element.

Fig. 7 shows a double element which is very similar to a Belleville

element, the difference being that the Belleville tubes are inclined to carry the flow from one row to the next, while in this the tubes are horizontal and the rows are connected by vertical boxes at the rear end. In the Belleville the boxes both front and rear are horizontal and the

FIG. 7.

element is like a flattened spiral. The Belleville plan makes the baffling difficult, whereas with horizontal tubes baffles of uniform shape can be used, and are readily removed and replaced by sliding them along the tubes and between the front boxes. The horizontal position of the

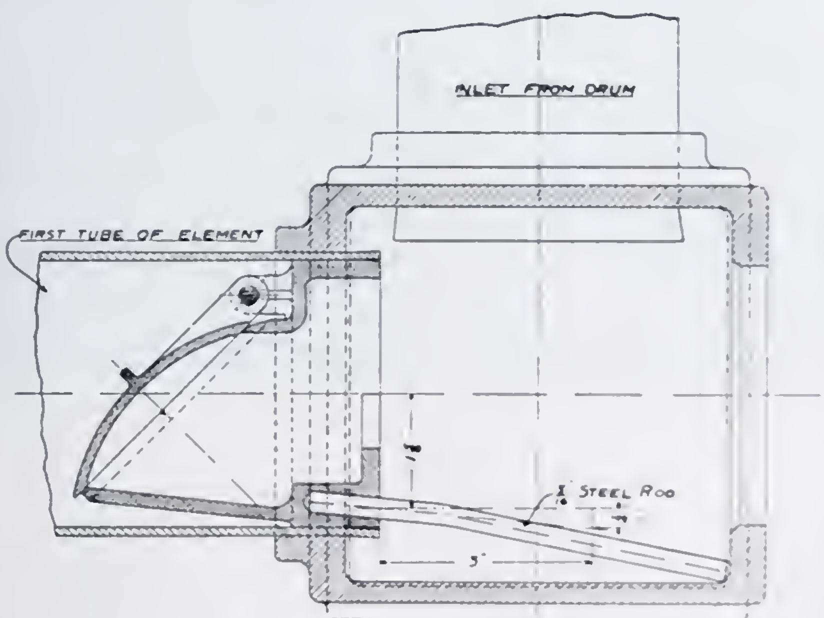


FIG. 8.

tubes also permits the separation of the front headers at any point more easily than if the tubes were spread like sheers. The inlet box is shown at the top rear end of the element. One inlet tube and box supplies two elements, and there are two check-valves in the box, one for each element. Fig. 8 shows a section of an inlet box with the

check-valve in position. It fits into the tube end and is held in place by a loose pin, which forms a positive stop when the hand-hole is closed. The valve is very loosely hinged, with plenty of clearance, and is so arranged as to be readily removed and cleaned.

Three and four wide elements have been tried, and work perfectly, but their capacity is necessarily limited by their greater length for a given height. A 20-tube element 4 wide by 5 high has a capacity of about 70 H.P.; and an 18-tube element 2 wide by 9 high, about 100

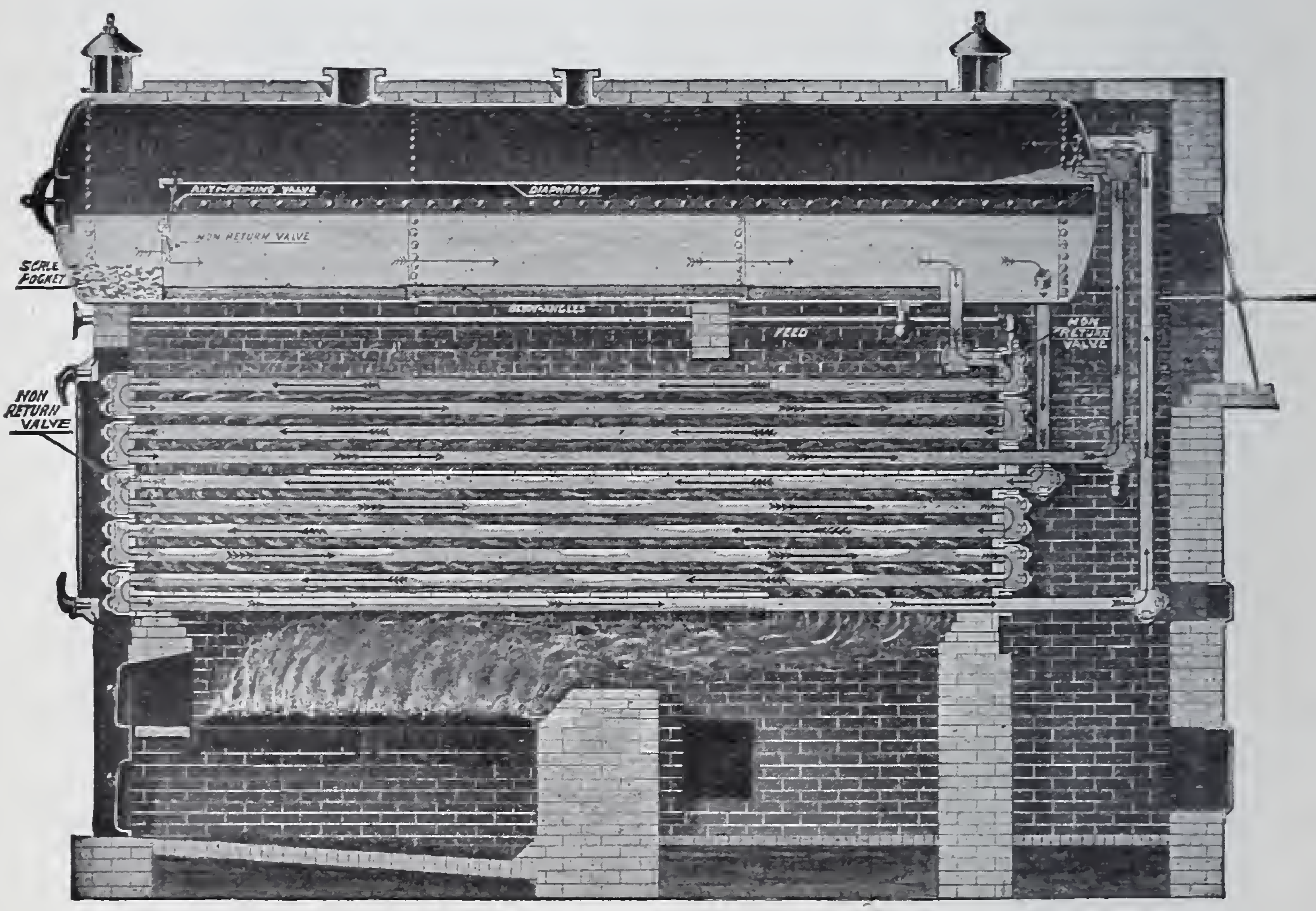


Fig. 9

H.P. If a 20-wide boiler be divided into five 4-wide elements, it will have a capacity of about 350 H.P.; and if divided into ten 2-wide elements, about 1000 H.P. (Boiler H.P. = 34½ lbs. water from and at 212° F.)

The double elements are limited to about ten tubes high. The failure of the vertical element type led to the division of the downflow into two stages, with the feed water going through the upper or economiser stage. The diagram (Fig. 9) shows this two-stage arrangement. As it is impossible to show the flow back and forth on the same level,

it is shown vertically downward. The lower elements may be two, three, or four wide, and the upper section may be all one element or may be divided into two or more elements. The economiser elements may contain from one-quarter to one-third of the total heating surface, and may be of any length up to 100 tubes. Economisers are in use 1800 feet long of 4-inch tubes.

Fig. 10 will give a clear idea of the construction of the two-stage type of boiler. All the front boxes are horizontal, and the rear ones in the economiser stage are horizontal except those next to the side walls,

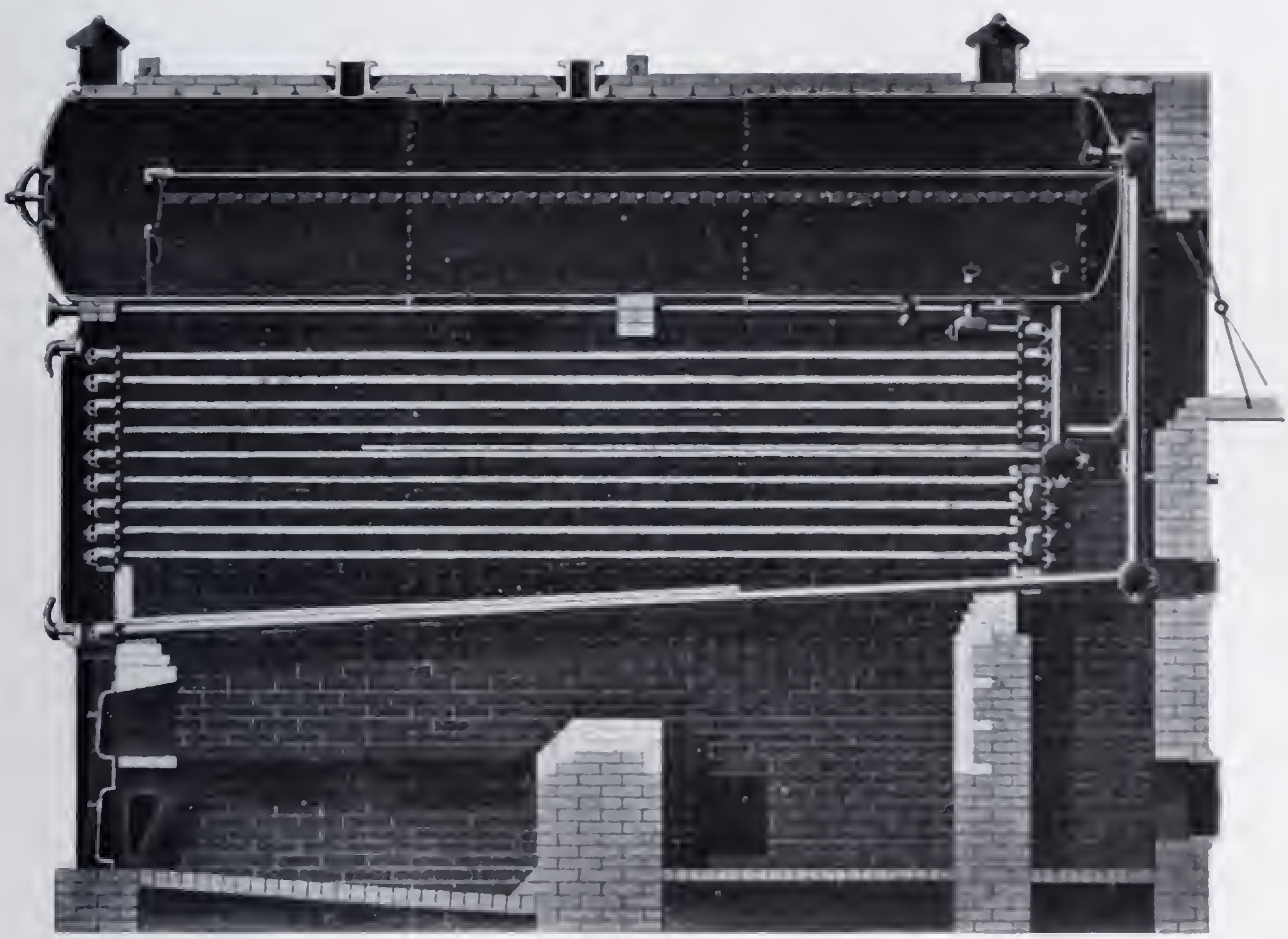


Fig. 10.

which are vertical to connect the rows. The feed-pipe runs from the front to the rear and discharges into the top economiser box, which is also connected with the drum. In the drum connection is a check-valve so placed that the feed water is forced to traverse the entire economiser stage, tube by tube, and is finally discharged into the rear end of the drum through the upcast at the side. When the feed is shut off, the drum connection furnishes the economiser with a circulation.

The front ends of the bottom row of tubes are dropped to provide a

space for dust and easy access to the tubes and baffles. The gases flow over the bridge wall through the combustion chamber, up and forward in the first pass, and back and under the wing wall in the second pass, and thence out through the damper at the rear end. The baffles are 2- by $4\frac{1}{2}$- by 9-inch firebrick made to fit the tubes, and are readily removed and replaced through the front.

Fig. 11 shows how the boxes are separated for replacing tubes. The elements are flexible and the front boxes can be raised to pass a tube at any point.

Fig. 12 shows a 20 by 9 boiler with superheater located in the com-

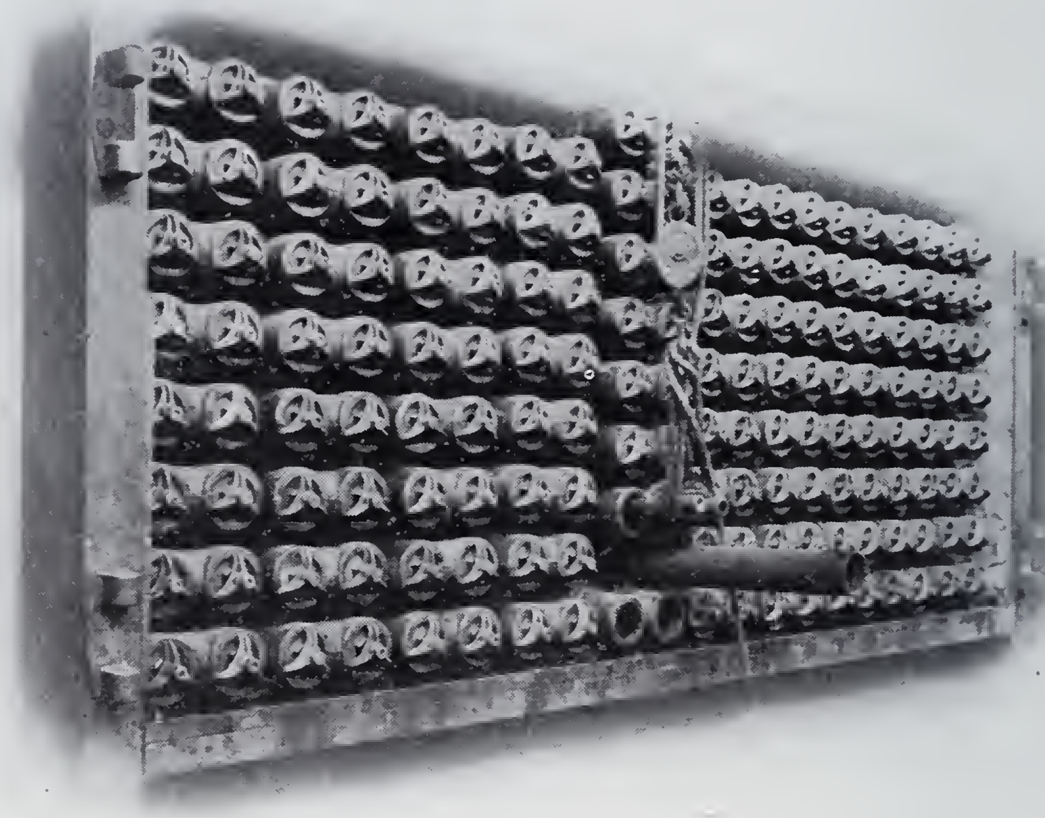


Fig. 11.

bustion chamber and the economiser suspended, leaving a dust-space above the second baffle. The boiler has ten 12-tube elements, two 30-tube economiser elements, and 32 $1\frac{1}{4}$-inch O.D. superheater tubes, the length of which is variable according to the degree of superheat desired. The superheater tubes are of seamless drawn steel bent into U form and connected to cast-steel headers by expanded joints. Four tube ends are grouped opposite to a standard 4-inch hand-hole, closed with a circular ground-joint cover, the same as is used in the boiler proper. The bottom headers are connected by tubes having expanded

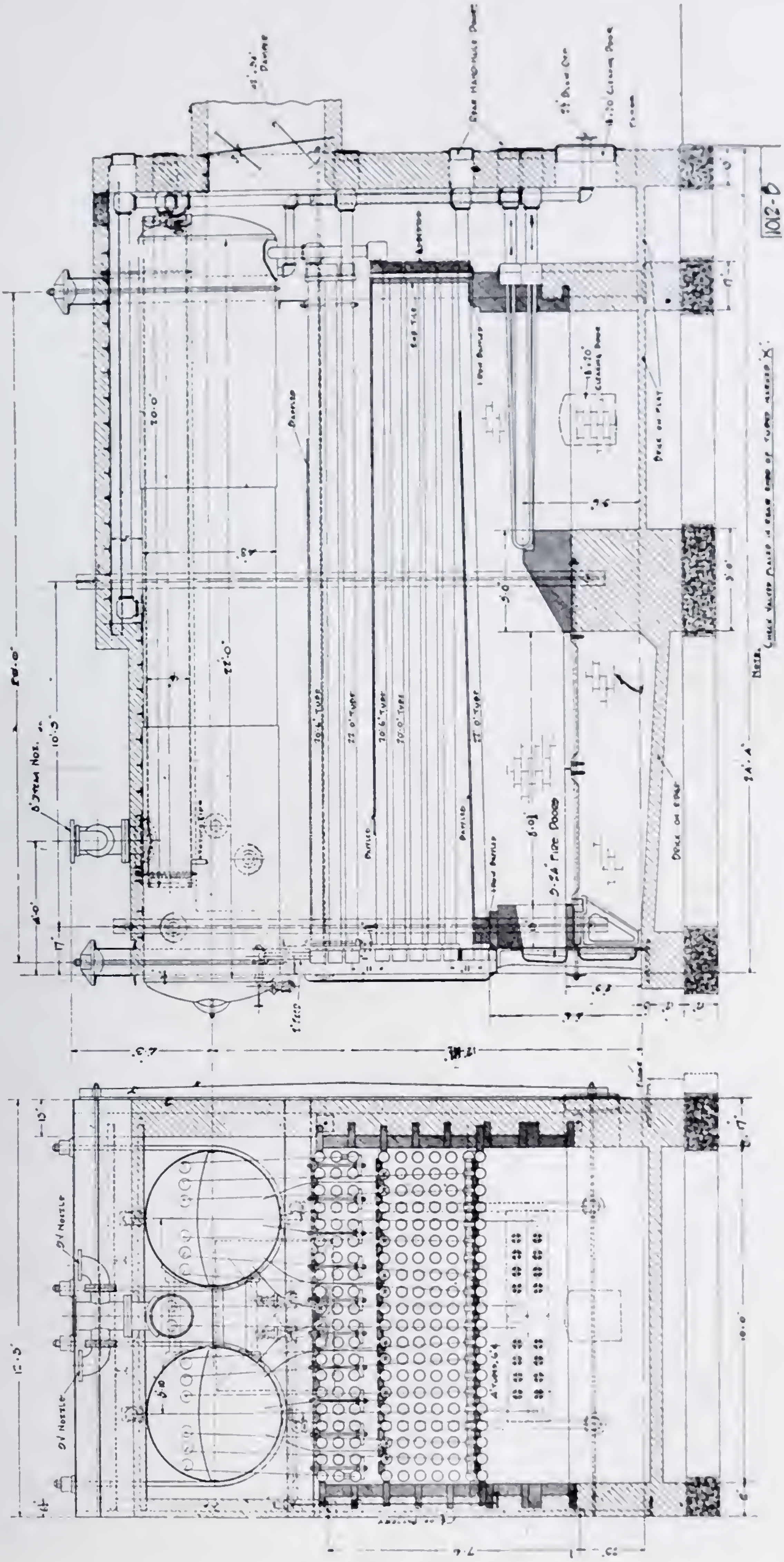


Fig. 12.

joints with the steam drums, and the top headers with the superheater drum, which is located between the two boiler drums at the top of the setting. The superheater fills with water when the boiler is tested by water pressure, and thereafter fills and drains itself automatically when steam is being raised or fires are banked and when putting the boiler in line afterward. The tubes are designed for a rate of flow which enables them to withstand the hottest fire perfectly. The apparatus is reliable and durable and requires no extra attention. The safety-valves are placed on the superheater drum, and this drum serves to steady the superheat temperature and as an automatic separator in starting.

The superheater is designed to maintain an approximately constant ratio of efficiency with the boiler proper under the widest variations of steam output, so that the superheat temperature remains practically the same with different rates of working. It should be noted here that the feed heating, evaporating, and superheating functions are located precisely as in the heat diagram, and the two breaks in the continuity of the flow but slightly affect the result. The addition of the superheater has added nothing to the radiation, waste heat, or combustion losses. Its fuel economy is, therefore, 100 per cent. against 40 to 50 per cent. for the best separately fired apparatus. The superheater drum is not an essential part of the superheater; there are about 30,000 H.P. at work without it. Its main advantage consists in doing away with the necessity of flooding and draining the superheater every time the boiler is started or put in line from a banked fire.

It has been a surprise to engineers that the superheaters do not burn out from being directly exposed to temperatures up to 3000° F. The superheating surface can be made fully as effective as the boiler surface in contact with water; it is only a question of carrying away the same number of heat units in the same time from each square foot of surface to make one square foot stand the fire as well as another. Some have asked what happened when the flow of steam stopped. The answer is that then the fire stops, or, in other words, the flow of steam cannot slow down or stop without slowing down or stopping the fire. There is undoubtedly a lag at times between the changes of the fire and the flow of steam through the superheater. Changes in the rate of feeding and rising and falling pressures have some effect, but the economiser helps to steady the varying feed effect, and the high rate of heat transmission secured in the design gives the superheater such a range of capacity as to enable it to meet all conditions of operation

with safety. Small tubes will withstand a high temperature better than large tubes, but their main advantage is in their higher heat-transmitting capacity per square foot of surface for a given frictional loss in pressure. This type of superheater gives a very uniform temperature at the engine with varying loads and under all conditions. This is because the transmitting efficiency of the evaporating and superheating surface rise and fall together with change in the fire. Inequalities in the fire, of course, cause some fluctuations at the boiler, but these form short heat waves which neutralize each other in the steam-pipe. It is not fluctuations of this character which cause trouble. The heat waves must be of considerable length to reach the engine or to have an injurious effect after reaching it. Some superheater builders have attempted to secure uniformity by covering the superheater tubes with heavy cast-metal or firebrick. It is quite easy to see that this accomplishes no more than to take up the short heat waves in the fire. *It steadies the temperature of the furnace gases rather than the superheat.* Of course, if the flow of steam is steady, the superheat will be uniform until changes in the rate of working occur, when it is perfectly plain that the superheat must rise and fall, and these waves will be of sufficient length to reach the engine. The superheater is not the place to store heat from the furnace gases. If heat storage is necessary to steady the temperature, it should be in the form of a steam reservoir which would absorb the heat waves of the entering steam. Brickwork or heavy cast-metal around the superheater tubes makes them very slow in transmitting heat, so they cannot respond quickly to variations in the flow of steam.

Where large tubes are used with internal tubes to keep the steam in contact with the superheating surface, there is twice as much frictional drop in pressure as is necessary to do the work. Some have an idea that cast-iron will stand the fire better, but the writer has seen the cast-iron covered superheaters removed from boilers as badly burned and warped as possible. Some have an idea that in a separately fired superheater the temperature can be better controlled than in the boiler, and that it is possible to increase or reduce it at will. In the first place, it is a great mistake to think that it is desirable to change the degree of superheat in a power plant. Changes cause trouble, and it is not possible to control the degree of superheat either by hand or by thermostat regulators anywhere near as closely as can be done in combination with the boiler. With superheaters placed in an intermediate position in the boiler or near the flue, the heating surface

has to be multiplied, its efficiency is reduced and temperature control is lost, since no efficiency ratio can be maintained with the boiler surface. The superheat either disappears at low rates of working or reaches a dangerous degree when the boiler is forced.

The author designed a double-ended water-tube boiler in 1900, and a cut of it was shown in our first catalog. Our fellow-member, Mr. W. S. Twining, chief engineer of the Philadelphia Rapid Transit Company, was the first to recognize the possibilities of the double-ended design, and gave the writer an opportunity to convert one of the first six double-ended boilers in the Second Street and Wyoming Avenue plant to the double-ended design. It was found that about 75 per cent. could be added to the power, with no loss in economy, by simply doubling the grate surface, without any change in the passes. By removing the rear wall and putting a steel casing around the rear connections, the boiler was actually shortened $3\frac{1}{2}$ feet on the floor, and this added sufficiently to the space at the rear end to make an ample fire-room. All the boilers have since been double-ended, and the capacity of the plant has thus been increased 75 per cent. without adding in any way to the ground area.

Double-ended marine boilers are, of course, very old, but they are really two separate boilers placed back to back, and there is considerable floor space wasted between the grates. Some Hornsby boilers have been built in England fired from the sides, but the extra firerooms between them offset the gain.

Grate surface is the cheapest thing that can be added to increase the power of boilers, and is also the most efficient, if it can be arranged to be fired properly. Less than half the floor space under the standard water-tube boilers with 18-foot or 20-foot tubes is utilized. Increase of draft does not increase the power in the same ratio as increase of grate. It costs more, and the fuel economy falls off rapidly. Forced draft is also harder on boilers.

Trials of a boiler with a fire-box $9\frac{1}{2}$ feet wide developed the following results: With buckwheat anthracite coal the boiler developed single-ended 350 H.P., and double-ended 690 H.P., with practically no loss in economy; while with forced draft single-ended 470 H.P. was developed with a falling-off in fuel economy of about 16 per cent. In the double-ended tests the stack draft was increased, so that with the increased friction through the passes the draft in the fire-box was about the same. The sustained economy of the double-ended boiler is due, first, to the fact that considerable saving in radiation is effected by

placing the second grate in the same setting; second, the increased friction makes the heating surface more efficient; and, third, the larger fuel bed, properly fired, secures equal or better combustion, with less surplus air, owing to the horizontal baffling, which causes surplus air from the front grate to pass over and help support combustion on the rear grate, thus reducing the surplus through that grate. The reason for the rapid falling-off in economy with forced draft is because the increase in draft pressure tends to cause the air to seek thin places and burn holes in the fire-bed. The gas explosions which occur with forced or balanced draft indicate stratification and imperfect combustion.

Fig. 13 is a double-ended boiler with Roney stokers. There are 16 of these boilers in the Delaware Avenue plant of the Philadelphia Rapid Transit Company. The drums are 54 inches in diameter and the tubes are 4 inches by 20 feet long. The superheaters are located over the rear grate and the superheat is about 125° at the boilers. There are three passes; the economiser section, forming the third pass, is divided into two elements. In the second pass there are five 4-wide intermediate evaporating elements, and the first pass contains ten double evaporating elements. The fire-box is 10 feet wide, which is a standard width for 450 to 500 H.P. single-end units, and they have been tested up to something over 1100 H.P. When run at these high rates, the flue temperatures are under 500° F., and when run single-ended recently at about 435 H.P. the gases were down to 315°, while the temperature of the steam was 500° F.

The success of these double-ended boilers has led to the double-ending of the inclined tube boilers in power-house of the New York City Railway at 59th Street and North River. This has been accomplished by lowering the floor at the rear end of the boilers 4 feet and replacing the rear brickwork with a steel casing and installing stokers. An ample fireroom has thus been secured at the rear without moving the boilers, and 75 per cent. will be added to the capacity of the plant without any additional land or buildings.

Fig. 14 shows standard 1-, 2-, and 3-pass arrangements of the elements in diagrammatic form. The lines indicate the general course of the water through the tubes. In the one-pass arrangement, No. 1 shows four double elements with two inlets and no economiser. No. 2 shows two 4-wide elements of 20 tubes each without a feed element. No. 3 shows four 10-tube double elements and one 8-tube feed element. No. 4 shows two 16-tube 4-wide elements and one 8-tube feed element. No. 5 is a 2-pass arrangement with four double elements and one feed element

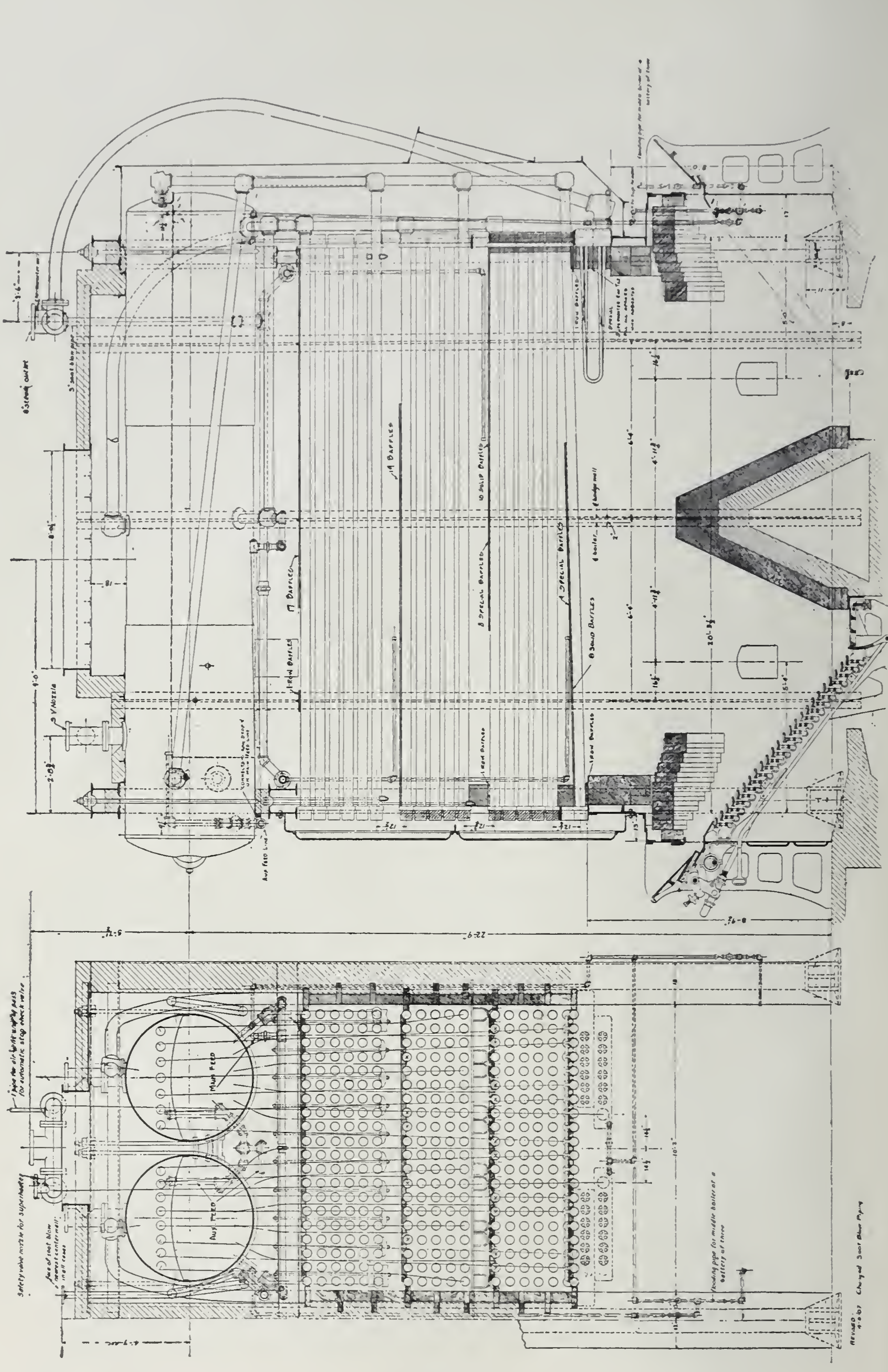

19 BAFFLES
17 BAFFLES
IRON BAFFLES
8 SPECIAL BAFFLES
4 SPECIAL BAFFLES
8 SOLID BAFFLES
10 SOLID BAFFLES
MAIN FEED
AUX FEED

Fig. 13.

with space between. No. 6 shows 3-wide elements, which have been used in one or two cases. No. 7 shows a 4-wide arrangement. No. 8 shows a 3-pass arrangement with one feed element in the third pass, two 4-wide intermediate evaporating elements in the second pass, and four double elements in the first pass. No. 9 shows a 3-pass arrangement with two feed elements in the third pass, four intermediate evaporating elements in the second pass, and eight double elements in the first pass. Any size boiler can be built by merely multiplying the junction boxes and tubes, and special parts are thus avoided.

The circulation indicator (Fig. 15) shows diagrammatically an ar-

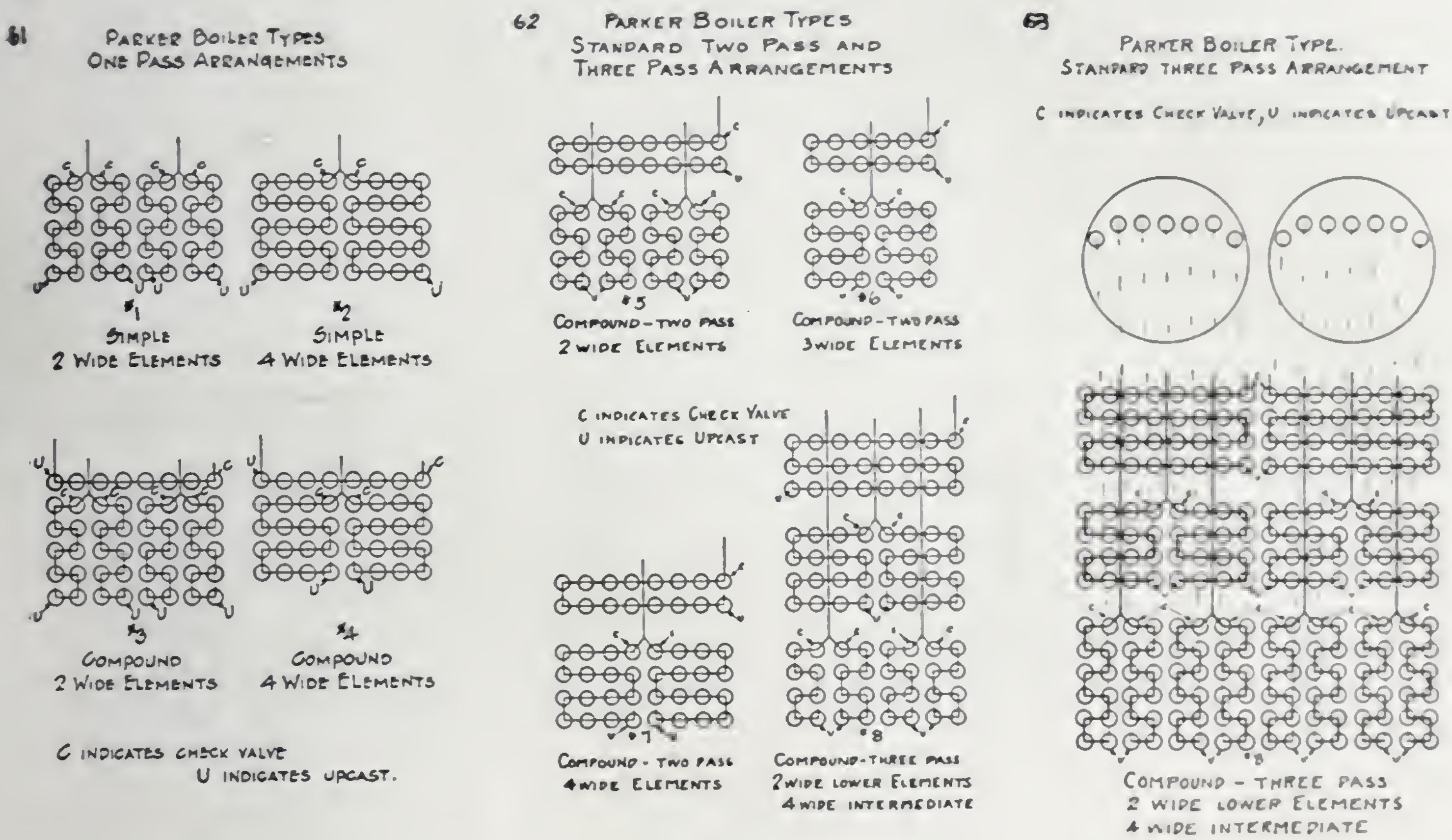
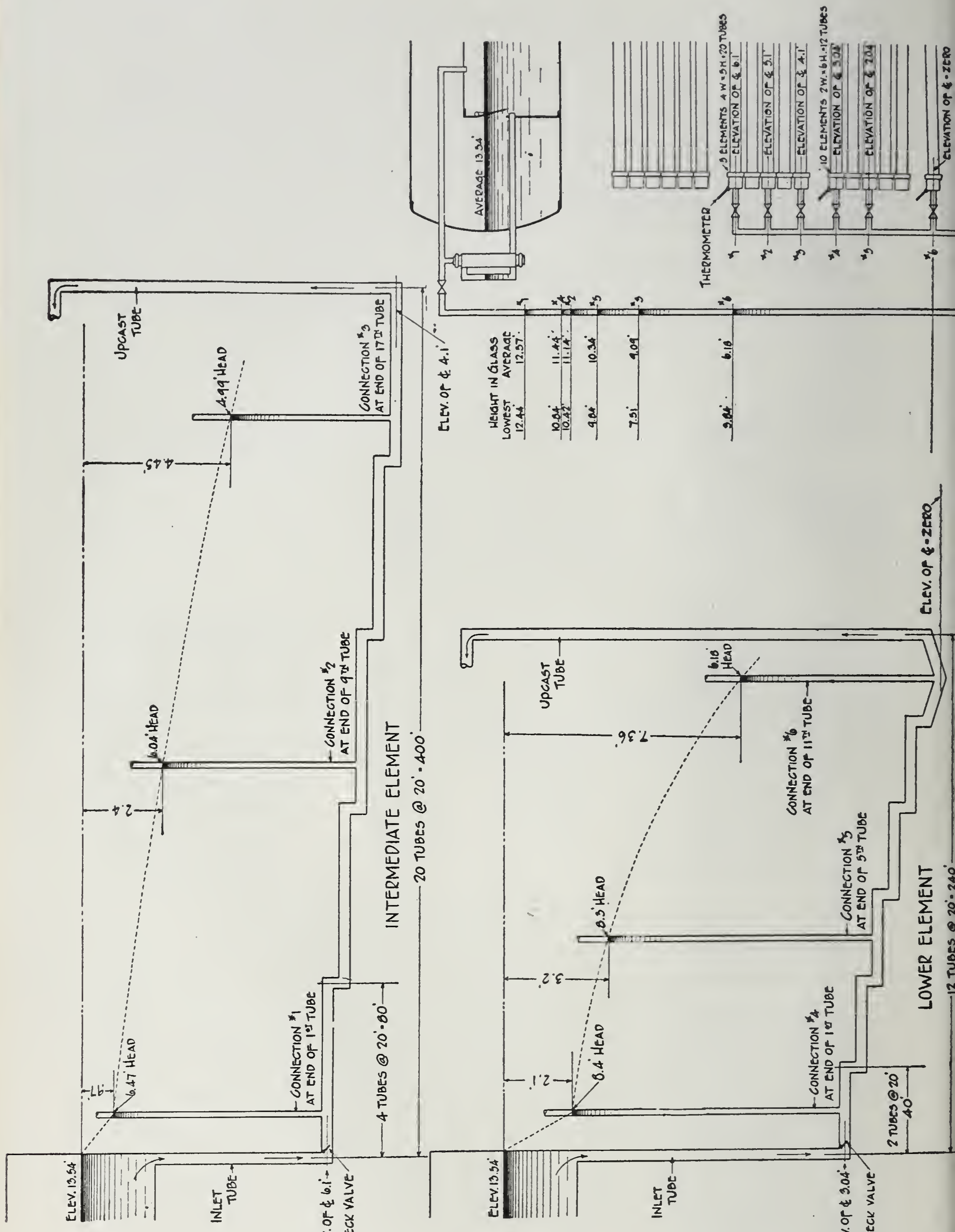


Fig. 14.

rangement tried on an 800 H.P. double-ended 3-pass boiler. Three junction boxes in one of the intermediate elements and three in a lower element were tapped and connected to a vertical manifold by small pipes, each controlled by a valve. This manifold was connected at the bottom end to a $\frac{3}{4}$-inch vertical pipe, on which was mounted a series of gage glasses, forming a continuous water column. The upper end of the pipe was connected to the top of the regular water column. Thermometers were inserted in the places indicated, but no trace of superheat appeared in the elements at any time. With any valve open and the others tightly closed, the height of water in the indicator above the point of connection with the element shows the pressure-head at



INTERMEDIATE ELEMENT
20 TUBES @ 20' = 400'
4 TUBES @ 20' = 80'
ELEV. 13.54'
INLET TUBE
ELEV. OF ℄ 6.1'
CHECK VALVE
6.47 HEAD
CONNECTION #1 AT END OF 1ST TUBE
2.4'
6.04' HEAD
CONNECTION #2 AT END OF 9TH TUBE
4.45'
4.99' HEAD
CONNECTION #3 AT END OF 17TH TUBE
UPCAST TUBE
ELEV. OF ℄ 4.1'
AVERAGE 13.54'
HEIGHT IN GLASS
LOWEST AVERAGE
12.44' 12.57'
10.04' 11.44'
10.42' 11.14'
9.04' 10.34'
7.51' 9.09'
3.04' 6.18'
THERMOMETER
9 ELEMENTS 4W-5H-20 TUBES
ELEVATION OF ℄ 6.1
ELEVATION OF ℄ 5.1
ELEVATION OF ℄ 4.1
10 ELEMENTS 2W-6H-12 TUBES
ELEVATION OF ℄ 3.04
ELEVATION OF ℄ 2.04
ELEVATION OF ℄ ZERO
ELEV. OF ℄ ZERO
LOWER ELEMENT
12 TUBES @ 20' = 240'
2 TUBES @ 20' 40'
ELEV. 13.54'
INLET TUBE
ELEV. OF ℄ 3.04'
CHECK VALVE
2.1'
8.4' HEAD
CONNECTION #4 AT END OF 1ST TUBE
3.2'
8.3' HEAD
CONNECTION #5 AT END OF 5TH TUBE
7.36'
6.18 HEAD
CONNECTION #6 AT END OF 11TH TUBE
UPCAST TUBE

FIG. 15.

that point. The lowest readings noted and the averages of many readings are tabulated beside the indicator.

The upper diagram at the left shows the intermediate element straightened out, with indicator tubes located as noted. Vertical distances are drawn to the same scale as in the diagram of the boiler. The horizontal scale is one-fifteenth of the vertical scale. Water flows down the inlet tube and through the check-valve under a pressure head of 7.5 feet of water. It flows through four 20-foot tubes before dropping 6 inches to the level of the next four tubes. The pressure head at the base of the upcast is over 4 feet. The velocity head, plus all the frictional losses of head from the drum to any point in the element, are measured by the vertical distance of the gradient at such point below the water-level of the boiler. The dotted line shows the hydraulic gradient. Correction has not been made for the difference in temperature of water in the indicator and the boiler.

The third diagram similarly represents the lower element. Much more steam is generated here than in the intermediate element, and the gradient is correspondingly steeper. The element is 240 feet long, compared to 400 feet for the other. The inclination of tubes near the upcast is caused by the space for access to baffles. This element has an average head of nearly 6 feet to discharge the steam and unevaporated water through the upcast. The minimum head at high rates of working is nearly 4 feet. With these diagrams before us, it does not appear contrary to the laws of nature that the flow moves continuously from inlet to upcast, passing downward occasionally in its course through the tubes.

DISCUSSION.

Mr. Jackson.—Mr Parker referred to us having run one of these boilers for six years. That is so, and it has given us no difficulty whatever, except to cut down its capacity, which was done by carrying the load with two-thirds of the grate area. We have taken 150 horse-power constantly, with a little over one-third of the grate covered with brick.

I was very sorry to hear him tell us we had to clean this boiler, because up to now all we have done has been to take off the manhole cover and clean the drum. I still have faith that with the water we use we will not have to do any turbine drilling.

Mr. Parker's guarantee to us when our boiler was put in was, that if it did not do better than any other boiler we put alongside of it, he would make us a present of the one he put in. He did not have to make us a present of it.

President Spangler.—Mr. Parker had the kindness to bring my name a number of times into this paper. When he first brought the model into my office I laughed at him; I thought it was nonsense to put a naked gas flame on an

almost empty glass tube and expect the glass to stay there. However, he started up his model and did the work, and I am only sorry he does not have it here to-night. I think any one who has had anything to do with boilers would be surprised to see what really happens in it. It surely upset all my previous ideas of what did or could happen in the tubes of a boiler, and it shows how we all ought to acknowledge that we have something to learn every day.

I had the pleasure of testing the first little boiler that Mr. Parker made; also the one at Chester, and one in the Wyoming Avenue Station, and at one time I knew a little about the Parker boiler, my confidence became so strong that I bought two of these for the University of Pennsylvania.

Mr. Fennell.—I know the Parker boiler and cannot see why the tubes have to be cleaned at all. I believe I can run a Parker boiler in Philadelphia and never have to bore the tubes.

Mr. Parker said the boiler was safe. I want to say that it is the safest boiler in use. If a tube burns out in an inclined tube boiler, the water has access to two openings and expands more than 1600 times, making a great explosion, while with the Parker boiler, it has to flow through the check-valve and all the tubes and bends in the element. The velocity is then reduced and there is hardly any explosion in case of a ruptured tube.

P. A. Maignen.—If Mr. Parker had water for his boilers that could not make any sediment in the tubes, he would not have to provide means to remove the sediment. Improved generators for the vaporization of water as shown by Mr. Parker are most desirable. If the constructor of boilers were to start with the principle that no scale will form, he could use smaller tubes and arrange them so as to give the maximum of efficiency (without having to think as to where the sediment will form and how to remove it).

Water, which is the chief element in steam power, is the last thing generally thought of. The protection of the boilers from the danger of bad water is left to the care of makers of boiler compounds. The art of steam-generating would be greatly benefited if all materials susceptible of making sediment could be removed from water.

E. B. Carter.—What guarantee is there as to the amount of water evaporated with this boiler?

J. C. Parker.—Dr. Spangler has referred to our first meeting, ten years ago, when I showed him the model. It is true he threw some cold water on me, but it did me a great deal of good. I decided the thing to do was to build a boiler and get him to test it. When I got it built, he asked me to run it a week, burning about 25 pounds of coal per square foot of grate per hour, saying if anything was left of it he would test it. He looked surprised to see me back at the end of the week's run.

I heartily agree with Mr. Maignen that the thing to do is to purify the water before feeding it into the boiler when there is much scaling matter.

The water Mr. Jackson uses is very good, and the boiler has always taken care of it without any cleaning of the tubes, but in other places the tubes are now regularly cleaned, the same as with other water-tube boilers, except that the cleaning is easier on account of the broken, patchy condition of the scale in the tubes and the quantities of scale thrown up into the drums. There is also an

advantage in being able to use a steam-cleaner in the tubes without affecting the joints from the expansion of the tube in which the cleaner is used.

Mr. Fennell's methods may avoid the necessity of cleaning the tubes with some waters, but in many cases the tubes must either be cleaned regularly or the water purified outside the boiler.

Regarding safety, a ruptured tube merely empties the boiler, the explosive energy being absorbed in friction through the element. The anti-priming valve and diaphragm in the drum shuts off the flow to the upcast, and only the few pounds of steam in the steam space escapes through it.

Replying to Mr. Carter, an economy guarantee is dependent upon the character of the fuel and the test conditions. In the government tests at St. Louis the efficiencies ranged from 50 to 70 per cent. A proper guarantee cannot be made without knowing all about the fuel and conditions under which the test will be run. We make a practice of guaranteeing 5 per cent. better than other boilers when we know that accurate tests will be made under identical conditions, and we expect to get about 8 per cent. saving on account of our economiser feature.

Paper No. 1065.

FOUNDATION FOR THE BUILDING FOR THE U. S. NAVAL EXPERIMENT STATION AT ANNAPOLIS, MD.

HARRISON W. LATTA.

(Active Member.)

Read November 7, 1908.

Some years ago the presiding officer, in turning over to the Club for discussion a paper on somewhat the same lines as the one to be read to-night, remarked that not only the subject-matter but the treatment of it was unusual. This may have been due to the difference between the contractor's and the engineer's point of view, as most of our papers are written by those who are engaged in the profession of engineering, and not by those engaged in the business of engineering. However, they should not be so far apart, for the greatest economy consistent with the best results is the main end to be sought, except in matters of experiment and investigation, and even then the final aim is still the same, when the results of the investigation are given to the profession for use in active practice.

The subject of this paper, the foundation of the Experiment Station for the Bureau of Steam Engineering of the Navy Department, might well be supplemented by a review of the nature of the work to be done, and the results to be accomplished by the plant for which the building is constructed. The equipment would also make a most interesting paper, but it is a matter with which the author is not familiar, his work having only to do with the construction. The present operations comprise but half of the final plant as now planned. When the work is complete, our large battleships can be brought to this station and every detail of their mechanical equipment tested, their efficiency determined, and their weak points discovered and remedied.

Several years ago a thirty-foot channel was dredged from deep water in the Chesapeake Bay to the mouth of the Severn River, a distance of about four miles. This channel has maintained itself without dredging, so that deep-draft vessels can have access to the Annapolis harbor, which will eventually be dredged to thirty feet.

With a good harbor and ready access to the deep water of the bay, the location of the building opposite the Naval Academy is most advantageous. At this point of the river there is a shoal extending 500 feet from the north shore, covered by about a foot of water, the bottom falling off rapidly from this shallow water to a depth of thirty feet at a distance of eight hundred feet from shore. The building was located on this shoal with its outer end near this deep water. A dredged channel parallel with the building and thirty feet from it was to furnish the material for filling around the building and give access to it from the main channel. The building will eventually be surrounded by a sea-wall, but at present a wooden bulkhead protects it, and the fill around it, from the action of the water.

As stated, the outer end of the building (which is 300 feet long and 200 feet wide) was to be about four hundred feet from the shore-line. Test borings taken over this entire area showed a top crust of sand, underneath which was a stratum of mud, overlying a bed of fine sand. The mud disappeared entirely at the shore end and increased in thickness at the outer end of the building, forming a wedge with its wide part toward the river. A pile foundation was necessary, with piles ninety feet long for the outer end of the building, the lengths decreasing toward the shore.

Proposals were asked for the foundation and fill complete, including the bulkhead and the dredged channel from which the filling material was to be taken. The prices varied from $70,000 to $76,000, and the award was made at the lower figure. Accompanying this lower bid was an alternate proposition suggesting a number of changes looking toward a reduction in the cost, without any loss in the efficiency of the Station. Among the most important of these was the proposition to move the location of the building one hundred feet inshore and increase the length of the dredged channel by a similar amount. This greatly decreased the length and number of long piles required, and at the same time gave additional fill which was available for making more land around the building. The plans called for the fill next to the bulkhead to be made of oyster shells, and the rest to be of sand dredged from the channel. A considerable saving was effected by omitting the shells; their purpose was simply to prevent the sand being washed out through the cracks between the planks in the bulkhead. To accomplish this result, narrow strips of board were nailed over the cracks. As stated, there was a layer of mud under the top crust of sand; in dredging the channel the specifications allowed only the sand to be used

in the fill. The mud had to be scowed to deep water in the Chesapeake Bay, a distance of about five miles. An examination of the borings showed that the proportion of mud dredged from that part of the channel, where it would be available for fill, would be small, and when mixed with the sand and dried out would make fully as good filling as fine sand. A considerable sum was saved by allowing all this material to be used for fill. To still further economise, several other changes were made, particularly in the finish of the exposed surfaces of the tanks, pits, and pipe tunnels. The final result was a reduction of $12,000 in the cost of the work, which was $58,000 instead of $70,000, as originally estimated.

Operations were started by dredging the channel; sufficient material was taken out first to make a fill of about four feet over the area covered by the building, which brought the surface two feet above water-level, and gave solid ground on which to use the land piledriver, as the water was too shallow to use a floating driver. The first work done, after driving a few test piles to determine definitely the lengths required, was to put in the bulkhead, for with every storm a large amount of fill would be washed away from this exposed position, open on three sides to the waters of the river and bay. This was most tedious and expensive work; frequently the fill built up during the morning would be carried away in the afternoon before the piles could be driven to secure the bulkhead.

After the bulkhead was closed and the fill made, the next work was on the foundation piles. All the piles were southern pine, brought by schooner from Jacksonville and unloaded at the site of the work. Those who have never bought timber of this kind and shipped it by vessel have little conception of the vexatious delays and annoyances which are continually arising. The piles are usually purchased delivered alongside the vessel at the shipping point, subject to inspection at that point, and loaded by the vessel. The vessel is chartered to load and carry the piles to their destination, but as the inspection is made alongside the vessel while she is loading, it may happen, as did on one cargo, that with a liberal allowance for rejections, so many piles are condemned that there is not a full load of accepted ones ready for her. Demurrage rates are from $50 to $75 per day, so she cannot wait for more timber to be cut, and has to come away without a full cargo. To avoid this difficulty and make sure of having a full cargo, the inspection was made before the arrival of the vessel. The piles are hauled down, rafted up in the water, inspected, and ready for the

vessel when she arrives. In this case the vessel is sure to meet with head winds and make such poor time that on her arrival the timber is water-logged, the rafts broken loose, and many of the piles sunk, and again she must leave with a short cargo. As the vessel is chartered at a lump sum, these short loads greatly increase the cost of the freight. When shipping business is good, it is very difficult to get vessels to take piles, as they are troublesome to load, and stow away poorly. It is almost impossible to charter a vessel except for a lump sum, for the reason that there is always doubt about getting a full cargo, and because sizes of timber in the rough vary so greatly that the shipping agent can tell little from past experience as to how many linear feet his vessel will carry; the load depends altogether on bulk and not on weight.

The piledriver for this work was sixty feet in height, and as the specifications called for a three-thousand-pound hammer, it was built correspondingly heavy. In order to make the machine as light as possible, the boiler was not mounted on it in the usual way; a skeleton engine without boiler was placed on the driver. A central boiler plant was installed of sufficient capacity to furnish steam for the pumps and concrete mixer as well as the piledriver. In the case of the piledriver, which was of course being moved constantly, the connection to the engine was made by flexible copper tubing. The ordinary rubber steam hose will not answer for this purpose, as the sudden throwing on of the steam in raising the hammer causes it to burst. The piledriving for the building held out closely to the test borings; seventy- to seventy-five-foot piles were needed at the outer end and the lengths decreased to thirty-five feet at the shore end. The longest of these extended fifteen feet above the piledriver leads; they were put down with a water jet until the head came under the hammer. The driving started hard through the top crust, but as soon as the pile reached the stratum of mud it went down easily until the lower bed of sand was reached, when it gradually brought up to the required test of one-inch penetration for a blow of 50,000 foot-pounds. The piles, bringing up as they did in fine sand, where the supporting power was largely a matter of frictional resistance, varied considerably in length. However, in general the results were what were to be expected from the borings.

The piles were cut off at low water and capped with concrete, and as the fill had been only partially made, much excavation for the foundations was saved. The balance of the fill was made after the concrete

had been brought up to grade. The specifications provided for concrete in the proportion of 1 : 3 : 7; local sand and pebbles were used. With this rather lean concrete, thorough mixing was needed. All mixing was done by machine and the mixture made very wet. No particular attempt was made at a surface finish, as all the work was in foundations, but the concrete hardened up well and gave good clean-cut faces on the removal of the forms.

The pipe trenches and tunnels and pits were waterproofed with tar-paper and pitch, with excellent results; the only place where any difficulty was encountered was in the pump pit, and that was not caused by any defects in the placing of the waterproofing. This pit is eighteen feet wide by thirty-five feet long and thirteen feet deep, the bottom being six feet below mean low water. It is designed to support heavy pumping machinery. The foundation is on piles capped by a concrete slab reinforced by a grillage of steel "I" beams. Concrete walls, two feet thick at the bottom, form the sides of the pit. The waterproofing is placed inside these walls and is covered by a four-inch slab of concrete on the bottom and by four-inch brick walls around the sides. It was not expected that the concrete walls would be perfectly tight, and a sump hole was left in one end of the pit so that any seepage through the walls and rain-water could be pumped from it while the waterproofing was being placed. When the pit was completed and the waterproofing was all in place except the closing of the sump hole, the leakage through the bottom and the walls was six gallons per hour—not a great amount when it is considered that 1 : 3 : 7 concrete was used, that there was a head of water outside the tank of seven to eight feet, and that the heaviest part of the wall was but two feet thick. After the sump hole was closed and the waterproofing completed, there was no water coming into the tank. However, after twelve hours levels taken on the bottom of the tank showed that it had raised slightly, and there was a hair crack down the center of the concrete slab. The waterproofing was holding, but even with the small seepage the pressure of water was raising the bottom. The sump hole was at once opened, and the water drained out from below the waterproofing, when the bottom went back to its former position. It was decided to place a six-inch slab of reinforced concrete over the bottom of the pit to take the water pressure. This was done and the sump hole was allowed to remain open so that the pit could be pumped out; there was no roof covering it and all the drainage from the pipe trenches ran into it. It is interesting to note the results of this treatment on

the seepage through the concrete wall. At the time of the completion of the pit, January, 1907, there were six gallons per hour coming into the pit; in January, 1908, this had decreased to five gallons per twenty-four hours, although the sump hole was still open. During the year 1908 the water in the pit was for the most part kept lower than the water in the surrounding ground. The continued passage of water through the concrete causes a chemical change to take place which, together with the sediment carried by the water, fills up the pores. The author has known of this peculiarity of stopping seepage and small leaks by the passage of water through the body of the concrete, but has never before had so good an opportunity to demonstrate the fact in his own experience.

During the year occupied by the construction of the building the pit was exposed to the weather. From either this or some other cause the membrane waterproofing so deteriorated that dampness, and in places seepage, came through it and appeared on the brick lining of the pit. To stop these leaks numerous waterproofing compounds and paints were tried. The paints all required a dry surface and were therefore not available. Some of the anhydrous powders were found to be effective when they could be used in a considerable volume of concrete, but as the size of the pit could not be reduced by increasing the thickness of the walls, some method had to be found by which a plaster coating would hold back the water. Wunner's bitumen emulsion mixed with cement plaster and put on in two coats, each about $\frac{3}{8}$ inch thick, was found to fulfil the requirements. This plaster could be put on a wet surface, and even on a surface where water was seeping through the brick-work. The results were entirely satisfactory, and the inside walls of the pit were left perfectly dry.

The intake leading to the pump pit is a fifty-four-inch iron pipe ending in the intake well, which is located in the channel in a depth of about eight feet of water. In order to build this intake well—which is of concrete closed with an iron gate at the outer end—it was necessary to construct a cofferdam. The use of steel sheet piling was decided upon, for when removed the intake would be left clear and the difficulties avoided of removing a built up and clay-filled cofferdam. Sheet piling sixteen feet in length, of the ball-and-socket pattern, was used. The piles had a penetration of about six feet in the sand. In the ball-and-socket joint was placed a wooden spline to make the piling water-tight. However, the water came in so fast that it was impossible to keep it out sufficiently for work, until the joints of the piles

were caulked with oakum. This was done from the inside, as the pump lowered the water in the cofferdam. In this way the upper leaks were closed before the lower ones had sufficient head on them to make them serious. Each foot was caulked as the water fell, and then another foot gained, until the bottom was reached. After this the dam was comparatively tight, although considerable water came up through the sand bottom. When the intake was completed, the sheet piling was removed with no great difficulty.

The timber bulkhead surrounding the site of the building has been mentioned; this will eventually be replaced by a sea-wall; the piles in the bulkhead were driven with this in view; they will eventually furnish part of the support of the sea wall. The destructive action of the teredo is seen in the bulkhead. This seaworm is found in these waters only during June, July, and August, but one season was sufficient for it to eat away some of the three-inch planks of the bulkhead, leaving no more substance to them than in a sponge. A blow with the blunt side of an axe would go clear through the plank, even though the outside of the timber appeared to be in good condition.

Transportation was another difficulty on this work; as everything, including men, tools, and materials, had to be brought in by water, the location was as inaccessible as if it was on an island. The nearest railroad station was four miles away, and the condition of the roads cannot well be described.

When the final filling and grading are done, this contract is completed and ready for the builder. The foundation contractor, after working all year in mud and water, leaves a neatly leveled off piece of ground with nothing to show for his work but the tops of a few piers and foundation walls.

DISCUSSION.

(In reply to questions.)

Harrison W. Latta.—The waterproofing as specified and originally placed consisted of four thicknesses of one-ply tar-paper. This was light for a head of eight feet of water outside the pit. However, when first installed it seemed in good condition. After a year, either from the severe weather conditions to which it had been exposed or from some other cause, there was considerable seepage through the waterproofing and then through the brick lining. The preparation used to overcome this difficulty was Wunner's bitumen emulsion, about a quart of which was added to a batch of mortar formed by mixing a sack of cement with a cubic foot of sand. This was applied in two plaster coats, and was entirely successful. The material looks and smells like coal-tar. Mixing it with cement is a discouraging task till the results appear.

As originally designed the floor of the pit, which has about eight-foot head of water under it, had a four-inch plain concrete floor covering the membrane waterproofing. The water-pressure raised this floor, and to hold it down a six-inch reinforced slab was placed over it, the reinforcing rods extending under the side walls as far as, but not through, the waterproofing.

The decrease in seepage through the concrete walls during the year the pit was left open I think was due to material filling the pores in the concrete. This material was partly that carried in suspension by the water, and partly a material like laitance, due to some chemical change.

The use of concrete piles had been considered for the work. However, as the strata of sand over the mud was only fifteen to twenty feet, not sufficient for support, the length would have necessarily been sixty to seventy feet, which was prohibitive.

There seems to have been some confusion between the subject of this paper and one describing the sea-wall at Annapolis, which was an entirely different operation, on the opposite side of the Severn River from the Experiment Station. It was in this sea-wall that the concrete, which was a 1 : $2\frac{1}{2}$: 5 mixture, was deposited under water. The placing of this concrete under water caused foaming due to laitance. It was necessary to keep this material from depositing on top of the concrete, and to accomplish this, each day the section of concrete which was being placed was brought above water. The laitance was thus forced out of the forms and away from the concrete, and did it no damage.

SEWAGE PURIFICATION WORKS VISITED IN EUROPE.

ADDRESS BY GEORGE S. WEBSTER.

(Active Member.)

March 7, 1908.

In January, 1908, Mr. George R. Stearns, Director of the Department of Public Works, and myself were commissioned by the Hon. John E. Reyburn, mayor of the city of Philadelphia, to investigate the question of sewage purification, and to visit a number of plants typical of the various methods of disposal in use in England and on the continent of Europe, with a view of determining the best method to be adopted in treating the sewage of the city of Philadelphia.

In pursuance of this commission a number of plants were inspected in northern England, Germany, France, and other places on the European continent. Considerable data were collected and many reports obtained. As we returned only one week ago, we have not had sufficient time to tabulate and put in proper form the information collected.

A number of the interesting features and some of the facts, together with stereopticon views of the most important places visited, showing the plants in operation, may be of interest.

In order to have a clearer understanding of the purpose for which these investigations were made it will be well to refer to the statute of the State of Pennsylvania, approved April 22, 1905, and in force at the present time, in relation to the sewage problem. The act is entitled, "An Act to preserve the purity of the waters of the State, for the protection of the public health." Section 4 of this act reads as follows:

"No person, corporation, or municipality shall place, or permit to be placed, or discharge, or permit to flow into any of the waters of the State, any sewage, except as hereinafter provided. But this Act shall not apply to waters pumped or flowing from coal mines or tanneries, nor prevent the discharge of sewage from any public sewer system, owned and maintained by a municipality, provided such sewer system was in operation and was discharging sewage into any of the waters of the State at the time of the passage of this Act. But this exception shall not permit the discharge of sewage from a sewer

system which shall be extended subsequent to the passage of this Act. For the purpose of this Act, sewage shall be defined as any substance that contains any of the waste products, or excrementitious or other discharges from the bodies of human beings or animals."

The term "waters of the State" used in this act is defined in Section 1 as follows:

"Be it enacted, etc., That the term 'waters of the State,' wherever used in this Act, shall include all streams and springs, and all bodies of surface and of ground water, whether natural or artificial, within the boundaries of the State."

The city of Philadelphia, in pursuance of this act, has filed with the Health Department at Harrisburg a comprehensive plan of the main sewerage system, and from time to time forwarded plans of tributary sewers to be constructed, all in conformity with the general plan, and has received permits authorizing the extension of the sewerage system and the construction of new sewers, each permit, however, containing the following conditions:

"In view of these and other considerations, it has been unanimously agreed by the Governor, Attorney-General, and Commissioner of Health, that the interests of the public health demand that approval be given, and I do hereby and herein give approval for the extension of the sewers as designated by lists and plans forwarded under the following conditions and stipulations:

"That the City shall, on or before the year 1912, prepare and submit to the State Department of Health for approval, a comprehensive plan for the collection and disposal of the sewage of the five districts into which the City is divided.

"2. That the City shall, in the interim, forward plans and lists of sewers authorized to be built by the Councils of the City, from time to time, giving the name, size, length of each sewer extension, referring by number to the positions of said extensions upon the plans, to the State Department of Health, which extensions shall be immediately approved provided some progress shall have been made each year on the comprehensive plan for the entire district in which the sewer is located."

The situation, therefore, which confronts the city to-day is that on or before the year 1912 it shall have prepared a comprehensive plan for the collection and disposal of the sewage in all the districts into which the city is divided, and in the interim it shall make progress toward the completion of the plan.

With this condition confronting the officials charged with the care of the sewerage system it was deemed advisable to obtain all the in-

formation available. England, on account of the density of its population, the comparatively small flow of water in its rivers, and the existence of Conservency Boards with power to prevent or lessen the pollution of streams, had, of necessity, constructed works for the purification of sewage at a much earlier period than America. It was believed that much could be learned by visiting and coming in contact with engineers and experts handling problems of this kind in that country, and also by visiting works on the continent of Europe, and that the knowledge so obtained would be invaluable to a large city like Philadelphia, which is about to inaugurate a system of purification larger than any heretofore constructed.

From the plants inspected we find that there are five distinct methods for the treatment of sewage:

First: Land irrigation, which represents the old method of treatment used in some of the cities of England, and in Berlin and Paris. It is practically the irrigation of farm land with sewage, and gives very satisfactory results, where the nature of the soil and the cost of land make it practicable. The land is plowed into furrows and the sewage discharged so as to be distributed over it. The conditions existing in Berlin will give some idea of the land required for this method of disposal for a large city. The sewage of that city, amounting to 66,000,000 gallons per day for a population of 2,200,000, is treated upon land or sewage farms located in the suburbs of the city. Upon these farms vegetables, hay, grain, and fruit are raised. The area for the treatment of the sewage is about 40,000 acres, or about 62½ square miles of territory, equivalent to one-half the area of the city of Philadelphia. The topographical conditions surrounding Berlin and the nature of the soil make this method practicable. Berlin has the separate system for collecting the sewage, the storm-water being discharged directly into the river.

The sewage of Paris is carried to two farms in the suburbs for land treatment. It amounts to about 118,000,000 gallons per day for a population of 2,800,000. The treatment appears to be satisfactory. Fifty thousand buildings in Paris are connected with the sewers, and thirty thousand buildings have no connection, but are drained into sealed wells which are periodically pumped out into tank wagons and the contents hauled to and deposited on the land. A portion of the sewage from the suburban districts adjoining Paris is discharged into the outfall sewers from the city. A plant for the treatment of another portion of the suburban sewage is now in course of construction, and

is designed to treat about 8,000,000 gallons per day. Two methods are being provided: first, double contact; second, double percolation. Cinders are used as the filtering material in both cases, provision being made for sedimentation after the sewage passes through the percolating beds.

The topography, soil, and availability of land adjacent to Philadelphia are not such as to warrant the construction of a plant for land treatment in Pennsylvania.

Second: Treatment by dilution. This method is in vogue in Hamburg, Cologne, and a number of other German cities. The sewage is collected at one or more central stations, and passed through a grit chamber at a reduced velocity so as to allow the heavy inorganic matter to settle. It is then thoroughly screened and discharged directly into the river, the large volume of which is sufficient to so dilute it as to make it unobjectionable. In a number of cities, especially Hamburg, large areas of land have been purchased at some distance from the populous section of the city with the view of ultimately giving the sewage further treatment when the necessity shall arise and the best methods of treatment are determined upon.

Third: Chemical precipitation. This method consists of adding to the raw sewage, after it has passed through a grit chamber and been screened, a percentage of lime and salts of iron (copperas) or alumino-ferric to cause rapid precipitation. This method, when used upon such concentrated sewage as that of London and Leeds, does not give entirely satisfactory results, and the effluent is objected to by the Conservency Boards of these districts. It, however, removes much of the suspended matter, but produces large quantities of sludge, how to dispose of which is a serious problem for inland towns. From the best statistics we could obtain the sludge resulting from this method of treatment amounts to approximately 800 tons per day from a population of 500,000; the sludge containing about 90 per cent. water.

London treats its sewage by chemical precipitation at two stations on the Thames River east of the city, one located at Barking, and the other at Crossness. The close proximity of the North Sea enables the authorities to ship the 8000 tons of sludge produced daily 54 miles to sea. At Crossness 125,000,000 gallons, and at Barking 150,000,000 gallons of sewage, dry-weather flow, are treated daily.

Fourth: Contact beds. These are practically filters composed of brick, broken stone, coke, or cinder, generally four to five feet in depth, upon which the sewage is discharged, allowed to stand a short time,

and then drawn off, and the bed aërated, giving opportunity for aërobic bacterial action. These beds cannot be operated rapidly and, therefore, require large areas of land, but the economy of construction is such that this method is worthy of careful consideration.

At Manchester, where 36,000,000 gallons of sewage are treated daily by passing through grit chambers, screens, large sedimentation basins, and finally on contact beds of power-house cinder four feet in depth, the effluent is not satisfactory, and the authorities are constructing another series of contact beds. Experimental plants on a large scale indicate that fairly good results can be obtained by double-contact treatment when the sewage is somewhat diluted, but triple contact is required for concentrated sewage.

In this connection I may say that the solid matter, carried by the sewage on to the contact beds, fills the spaces, so that after a period of a few years they must be torn out, material washed, and the beds reconstructed.

Fifth: Septic tanks in connection with percolating filters. Septic tanks are large, generally uncovered reservoirs through which the sewage flows, remaining from eight to twenty-four hours, in accordance with the local conditions, depositing therein much of the suspended matter as sludge, which is gradually reduced in quantity by bacterial action. There is considerable difference of opinion as to the reduction of sludge by this means, some authorities claiming as much as 40 per cent., while others say there is not more than 10 per cent. It appears to be generally conceded that the digestion of sludge from domestic sewage, in tanks having a twenty-four-hour period, amounts to about 25 per cent. After the sewage passes through the septic tanks it is, in many cases, discharged upon percolating filters, known in this country as sprinkling filters, consisting of beds of broken stone, coke, or cinder from 6 to 9 feet deep, both material and depth varying in accordance with the judgment of the engineer. Upon the surface of these filters the sewage is distributed in the form of a spray by various mechanical devices. One form of distributor consists of four tubular arms connected to a vertical tubular shaft, the arms revolving in a horizontal plane. The sewage is intermittently distributed over the beds by the arms, which are perforated in such a way as to give uniform distribution, the spaces between perforations being greater near the center of the bed. A head of about 18 inches is sufficient to operate the sprinklers when the beds are not more than 60 or 80 feet in diameter, but when of greater diameter electric motors are used. Another

mechanical distributor in use at Bolton, in northern England, was constructed on the principle of the over-driven water-wheel. The sewage is discharged from cups on one side of the water-wheel, so that the apparatus moves in the direction toward these cups. As soon as the end of the filter is reached, a lever collides with a buffer and causes the current of sewage to be deflected to a series of buckets on the other side of the water-wheel, so that the apparatus moves automatically backward. It has been in operation for a number of months and was giving every satisfaction with regard to the reliability of its automatic action.

The third method of distribution is from fixed nozzles, spaced generally 10 feet apart, and so arranged as to spray the sewage over the beds.

In the percolating or sprinkling filters the sewage trickles or filters through the bed, a thin film of liquid surrounds each stone, and the effluent issues from below generally freed from putrescent matter. This method is gaining favor in England and France and is rapidly superseding other methods, the advantages being simplicity of construction and the more rapid rate at which the sewage can be treated and the consequent reduction in area of land required. Percolating filters are operated at the rate of from 800,000 to 1,500,000 gallons per acre per day.

At almost every plant visited it is the practice to remove as large a percentage as possible of the solids by mechanical means, the sewage being passed through grit chambers at a reduced velocity and then through fine mesh screens. In some cases the screens are movable and are automatically cleaned by fixed brushes. In other cases the screens are fixed and the cleaning apparatus movable; good results are obtained in both cases.

It is difficult to draw the line between a sedimentation basin and a septic tank, for septic action takes place in both; the action is less, however, in the sedimentation basin in proportion to the velocity at which the sewage passes through it and the frequency of cleaning.

There is much less odor from comparatively fresh sewage distributed upon a percolating filter than from septic sewage; also the deposits which collect in a sedimentation basin are not as objectionable to handle as septic sludge. It is necessary to consider these facts in locating a sewage purification plant.

The largest plant visited using septic tanks and percolating filters was at Birmingham, England, where there is treated a daily dry-weather flow of 22,000,000 gallons of sewage from a population of

900,000 residing in the city and adjoining districts. The sewage as it reaches the works is passed through grit chambers, where the velocity is reduced and the detritus settled out. It is then passed through preliminary septic tanks without scum boards into secondary septic tanks provided with scum boards. No screens are provided for the sewage as received at the works, but the sludge from the septic tanks, which is pumped to low lands several miles distant, is screened to prevent the clogging of the pumps. The sewage after passing through the septic tanks flows by gravity a distance of about five miles to percolating beds. Before being discharged upon these it is passed through tanks somewhat similar in design to the Dortmund tanks, to settle out as far as possible the remaining suspended solids to prevent clogging the nozzle distributors on the percolating beds. About twenty acres of these beds are in operation; they are worked continuously for about six months and then allowed to rest for about two weeks; by this method of operation it is found unnecessary to do any cleaning. The effluent from the percolating beds is passed through another set of tanks constructed on the Dortmund principle, to remove the humus-like solids before discharging into the river. The final effluent was clear and without odor. The material used for the percolating beds, which are 6 feet deep, is broken hard stone from $1\frac{1}{2}$ to 2 inches in diameter. The engineer in charge, Mr. John D. Watson, claimed that finer material will clog and necessitates the cleaning of the beds, and a larger material is not so effective, and that a destructible material such as cinder will break down and finally clog the bed. The quantity of suspended solids in the sewage which goes upon the percolating filter, if the filter is properly designed and the size of the material properly adjusted, is not decreased in passing through it, but only changed in character. That is, the bacterial action in the bed makes them generally non-putrescible; if discharged into a stream of water containing oxygen, they become non-putrescible. Beds of this character have cycles in which they will discharge more of the solids at one time than at another. The estimated cost of constructing percolating beds, including the underdrains, filtering material, and fixtures for distribution, is from $35,000 to $40,000 per acre.

At Salford, England, a city of 240,000 inhabitants, the method of treating the sewage is somewhat different. After passing the 9,000,000 to 12,000,000 gallons received daily at the works through grit chambers and screens, it is treated with chemicals; thence it flows through large precipitation tanks, and in order to further remove suspended matter

it is discharged on to roughing filters composed of fine gravel from $\frac{3}{16}$ to $\frac{5}{16}$ inch in diameter and 3 feet deep. These roughing filters are cleaned at least once a day by an upward wash in connection with air blown through them from pipes near the floor. The partially clarified liquid is then sprayed over percolating beds consisting of $\frac{1}{4}$ to $1\frac{1}{4}$ inch cinders and clinkers about 7 feet in depth from nozzles 5 feet apart placed in pipes laid in parallel lines 10 feet apart across the bed. The resulting effluent is clear and said to reach the standard of purity fixed for this district by the River Conservency Board, and is discharged directly into the Manchester Ship Canal. The sludge which results from sedimentation, screening, and chemical precipitation is collected into a receiving basin and pumped to tank vessels, which carry it to sea a distance of 64 miles. This plant produces about 1800 tons of sludge per week.

At Bolton, a city of 185,000 population, situated about 20 miles from Manchester, the sewage, after being passed through the usual grit chamber and screens, is discharged into a large equalizing tank having a capacity of 850,000 gallons, or about one-sixth the normal daily flow of sewage. The object of this tank is to equalize as far as possible the varying character of sewage coming to the works for treatment. The sewage at this plant is treated by chemical precipitation, supplemented partly by percolating beds with mechanically operated distributors, as heretofore described, and partly by intermittent filters six acres in extent and constructed of cinders 4 feet 6 inches deep. The latter are, however, being rapidly superseded by the construction of percolating beds for the treatment of the dry-weather flow of sewage, the intermittent filters being retained for the treatment of the excess storm-water flow.

At Accrington and Church 1,250,000 gallons, dry-weather flow, of sewage from a population of 50,000 are treated daily. The sewage upon reaching the works is passed through screens into large septic tanks, thence to percolating beds, where it is sprayed by mechanically operated distributors of the revolving type. The percolating beds are composed of coke or clinker from 1 inch to 3 inches in size and from 8 feet to 9 feet in depth. They have been in operation for a period of nine years without cleaning. Chemical precipitation was formerly used at this plant, but was abandoned on account of cost and unsatisfactory results; the precipitation tanks are now used as septic tanks.

The standard of sewage purification established by some River Conservency Boards in England is that a gallon of effluent shall not

absorb more than one grain of oxygen in four hours at 80° F. The Local Government Board has declined to publish standards to govern purity of effluents from sewage works, stating that standards must vary in individual cases.

It is also a regulation that in designing purification works provision shall be made for the treatment of three or four times the dry-weather flow, and that there shall be auxiliary beds for treating as high as six times the dry-weather flow; sewage diluted above that amount is allowed to overflow into the rivers.

The most serious matter confronting engineers at every sewage purification plant is the final disposal of the sludge. It is a nuisance while it remains at the plant and is costly to get rid of. Pressed sludge has practically no value as manure. At Bolton the farmers carted it away when they obtained it free of cost, but when a small charge was made they refused to take it. At all other places visited the disposal of the sludge was a matter of considerable expense. It is claimed that sludge contains some elements of value, but at present they are so diluted with inert matter that they are useless to the agriculturist.

It seemed to be the judgment of the engineers with whom we conversed that no general method for the treatment of sewage has been devised which is adaptable to all localities, but that the problems in each city must be studied and the method giving the best results adopted.

The great degree of dilution of the sewage of Philadelphia and the varying quantity and character of the manufacturing waste in different localities emphasize the importance of carrying to completion the experiments planned for the Spring Garden Testing Station.

PAPER No. 1066.

STATE HEALTH LAWS AND THE ENGINEER.

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Read February 20, 1909.

IN discussing the subject of preservation of the purity of the waters of the State by the construction of sewerage systems and sewage disposal works in which various kinds of household and manufactural wastes may be collected and treated and rendered suitable from either a sanitary or a pathogenic standpoint to go into the streams, it is quite important that the new State laws should be understood by the engineer.

The lawmakers have determined that there is a necessity for State regulation of waterworks systems and drainage systems. This is true with respect to practically all of the northern and central States. There has been more or less agitation about the necessity for the establishment of a national commission whose duties shall be to regulate the discharge of sewage into interstate streams. However, even if such a body were created, the conservation of the waters of a State would still devolve largely upon the officers of the State. Pennsylvania is concerned in the Delaware River, the Susquehanna, the Allegheny, Monongahela, Beaver, and Ohio Rivers, each of which is an interstate stream. It would be impossible for a national board to go as far in its work of compulsory discontinuance of the discharge of sewage into rivers and their tributaries as it is possible for the State authority to go, but even the State authority is limited, and very materially so. One of the great factors in the determination of what shall be done in any town in Pennsylvania respecting the treatment of its sewage is the question of municipal borrowing capacity. The State constitution limits indebtedness. Consequently it is readily seen that a legislative act, administered by an executive department, involving the expenditure of money in excess of the constitutional limit of indebtedness might not amount to much; in fact, the law could not be enforced under such a circumstance. There are a great many places

in Pennsylvania not able financially to assume the burden of expense of building a sewer system and of treating the sewage.

However, private capital may be induced, under proper regulation and guarantee, to make the improvement. This is the course usually pursued in small towns where the citizens want public waterworks and have not the borrowing capacity as a municipality to undertake the project. There are laws on the statute-books providing for the incorporation of drainage companies as well as water companies, and in this way several of the communities of the commonwealth have provided themselves with sewerage systems and sewage disposal works. These come under State supervision; they could not be regulated very well by a national board. The proper officials of the States of New York, New Jersey, Pennsylvania, and Ohio have adopted a common policy with respect to compulsory sewage purification works, in so far as such a policy can be made common under the different laws obtaining in these States.

The knowledge of how infection of certain diseases may be transmitted through water and cause outbreaks of the same disease in distant communities is common. Much has been written on the subject. Perhaps practical experience and careful observations have been more extensive in the State of Pennsylvania with respect to epidemics on this account than in almost any other State in the Union. Nevertheless, perhaps we fail to keep these facts in mind. There are so many natural agencies at work in the streams which operate to destroy pathogenic organisms or to disperse them widely, that it appears on first thought to be astonishing why a sweeping law should be enacted, making it prohibitory for anybody to discharge sewage into any stream or body of water. This is not Pennsylvania law. Discretionary power is vested in the Governor, Attorney-General, and Commissioner of Health with respect to the discharge of sewage from sewer systems owned by public corporations. The individual may continue to dispose of his sewage into the stream unless ordered to cease by the Commissioner of Health.

Several large epidemics of typhoid fever have resulted from the pollution of a water-supply by the discharges from one patient having the disease. On the uplands in mountain water-sheds, whose brooks are swift-running and on which simple intake dams are erected to divert the flow into the water-pipe leading to the town, the emptying of dirty water from a dwelling located most remotely on the water-shed may result in poison reaching the distributing pipe system in the town

in less than two hours. The specific organisms of disease have not perished in this short interval, and under these conditions it is very essential that no polluting matter whatsoever should reach the water-courses tributary to the supply of the town. There may not be more than half a dozen dwellings on the water-shed. It is simpler and cheaper to pay attention to the practices of sewage disposal at these six dwellings than to compel the installation of a water purification plant involving a higher tax on everybody who may use the water in the town.

But in the town where individual methods of household waste disposal give way to sewer systems the collected sewage of the entire community may be deposited at one point into a creek from which a number of miles below another town on the bank of the stream obtains its supply for public purposes, and in such an instance two things are essential: first, that the down-stream community shall filter the water; and, second, that the up-stream community shall purify the sewage.

It has been determined by the health authorities of New York, New Jersey, and Pennsylvania that both of these preventive measures should be adopted in the case cited. The apparatus set up to purify the creek water is like any other machine built by man. It is subject to wear and repair, to break-down, and to being overworked. Therefore, so long as there is pathogenic poison in raw water there is a risk to public health. The Butler epidemic was caused by the temporary repair of the water-filter and the admission of sewage-polluted water into the town service during this repair. The Royersford and Spring City epidemic of last year was due to overtaxing of the water-filter plant, whereby partially purified water was delivered into the homes of the water consumers.

There are two objects in view in the Pennsylvania law: namely, the abatement of nuisances and the removal of menaces. The former is unimportant compared to the latter. It is the pathogenic bacteria which do the great harm. They may be transmitted many miles in a flowing stream. It is a very grave matter, where there is the public health upon one hand, and the limited financial resources of the municipality on the other hand, to determine conscientiously how much risk is warranted before a water filtration plant or sewage purification plant shall be made compulsory. The degree of safety which these works afford is a debatable question, of course, and it should not be decided by the State authority in an arbitrary manner. Very thorough

investigation of the entire subject in every case should obtain, and this is the way the Pennsylvania law is being administered by Samuel G. Dixon, the first Commissioner of Health.

The municipal or consulting engineer has a very important part in the campaign. Take, for example, the problem of a new sewerage system and a sewage purification plant for a town. The expert employed by the city is not required to serve two masters. The State Department of Health is not a master. Its functions begin where the town's functions end. The engineer's duty is to his client, and in rendering the best service to his client he will follow the State regulations, which exist for the benefit of all towns and all the people. State sanction of the plans should mean something. In fact, it is a guarantee to the taxpayers that the object for which the sanitary works are designed will be accomplished. It would be futile for the State to compel the town to treat its sewage by a plan ill adapted to accomplish the work, or to bring about the establishment of a plant, and then, for lack of general oversight, witness lax maintenance and a failure of the works. Because the State's policy is a permanent one and involves in the aggregate the expenditure of many millions of dollars, as well as the preservation of public health, supervision of the operation and maintenance of works after they are built must obtain.

With this understanding of the proposition, it appears more clearly that the engineer in making up the original plans must ascertain all of the factors of the problem. He must know the volume of work to be accomplished by the plant; with respect to the sewage, he must know its characteristics and produce evidence that the plant designed to purify the sewage is adapted to the work; and when he has completed his plans he must submit them with a detailed report explaining the scope of the design, the results to be obtained, and the methods by which the results are to be obtained; and the specifications for the work may be required. In locating temporary outlets into streams and in selecting sites for purification works, preliminary advice may be secured of the State Department of Health. The Department's service is largely advisory and coöperative, if the engineer will but avail himself of the privileges. The site of a disposal plant is one of concern to interested parties. Complaints and petitions for or against any particular site, mostly against any particular site, are the rule. It is quite helpful to the engineer to receive advice from the State Department of Health on this subject, or else after he has prepared his plans for the erection of a plant on a specific site, the plans may be

rejected owing to the proximity of the proposed works to occupied estates or public highways.

Private corporations are more prone to seek this aid and to appreciate its value than are municipal corporations.

The nature of the State permits, issued by unanimous agreement of the Governor, Attorney-General, and Commissioner of Health, may well be studied by engineers. These permits are all printed in the reports of the State Department of Health. They afford a fund of valuable information, particularly useful to the engineering profession.

It will be observed by perusing the contents of these reports that conservatism has characterized the progress of the Department thus far in its history with respect to the administration of the laws to preserve the purity of the waters of the Commonwealth, and yet quite a little work has been done during the three and a half years in which operations have been under way. The work cannot be fairly measured by the actual number of sewage purification plants built in this time, or the actual number of water-filters built in this time. Each year is bound to see more work of actual construction accomplished. You will be glad to know that the necessity of the campaign is very generally recognized, and that the policy of the administration thus far in force has also merited wide-spread approbation.

People who have moneys invested in water companies express a sense of gratification that a firm and uniform policy relative to both public and private works has come to stay.

DISCUSSION ON TOPICS CONNECTED WITH SEWAGE DISPOSAL.

Henry Leffmann.—I would like to hear something in the discussion as to the relation of water waste prevention to sewage purification. The important item to my mind is the extreme dilution of sewage owing to the extreme waste. The pumpage figures for Philadelphia have been challenged more than once, particularly by Mr. Birkinbine, as being derived from the pumping-room and not from the actual pumpage. Reports of the Water Bureau show very clearly that there is an unnecessary waste of water in Philadelphia, and it is important that engineers and others who have charge of water-supply should consider whether they propose to take a stand—pretty positively—against this waste.

As water purification systems are extended and people pass from a polluted supply to comparatively pure water, unexpected sanitary conditions may appear, say within five or six weeks after the first supply of pure water has been turned on—conditions much to the discomfiture of city authorities. This has happened in Philadelphia and in Washington. The filtration plants had been expected to establish permanently a lower figure for typhoid, but it has been found that there was really an increase in typhoid. It is now well known in medical circles that the typhoid bacillus is not nearly so frequently conveyed to the human system by water as was formerly supposed. Other methods are not uncommon. Some years ago it was assumed that water was the only method of conveying this disease, but it is now positively known that contagion is an important factor. I missed a rare opportunity some years ago to discover this fact myself, for since the investigations have been published I find that the data were in my hands.

While in official connection with the Health Department of this city I investigated a local epidemic of typhoid in Germantown which seemed to originate from a pump which was located in the yard of a mill close to an open sewer. From inquiry of physicians associated with the cases, it was found that some of the patients had worked in the mill or had relatives living in the same house who worked in the mill, but were not always mill operatives themselves. The disease was probably conveyed from some one in the house.

There are what are known as "typhoid carriers." These may be persons who have had typhoid twenty-five or thirty years before. There is on record the case of a cook who was one of these typhoid carriers. Her movements were traced, and she seems to have carried twenty-eight cases of typhoid, mostly among other servants. There were about three deaths among these. Since modern methods of investigation have been developed, by which the germ can be detected, its presence in these individuals has been established beyond a doubt, and we will find, therefore, that sanitarians will be disappointed sometimes. They will establish a pure water-supply, a lot of typhoid cases will develop, and the authorities will be under criticism; the water will be said to be no good.

Howard Murphy.—Why is it that when pure water is turned into a raw water service, the typhoid death-rate almost invariably increases?

I happen to have the figures for Camden, where the typhoid death-rate has been lower than in any city of over 100,000 population in the United States. The death-rate used to be very high—nearly five cases per thousand—and when the artesian-well supply was introduced and the Delaware River supply discontinued, the cases after a severe epidemic fell to, I think, less than three per thousand; then again increased to over three cases per thousand. After the artesian well water had come into use and the water had been diluted out of the pipes, the death-rate descended to a good deal less than one-half of a case per thousand.

I want to know why it is that in the central part of Philadelphia, where filtered water has been turned on, in nine cases out of ten the deaths from typhoid increase almost immediately.

Henry Leffmann.—I do not want to divert the attention of the Club too much to these medical questions, but they have a bearing on this discussion. There may be disappointment upon the introduction of filtered water into a district. It is pretty well established that typhoid is due to a specific germ. It is recognized and called "Bacillus typhosus." Its general characteristics are well understood. It is also recognized that in drinking polluted water or milk, or, say, the eating of polluted foods, or coming in contact with a polluted person, you get in touch with the typhoid bacillus and other dangerous influences at the same time. If these other organisms are in sufficient proportion to modify the action of the typhoid bacillus, you will have a disease which is not true typhoid, and physicians diagnose this as "paratyphoid,"—near or just beyond typhoid,—and consequently

it is very probable that in summing up the cases of an epidemic there will be some confusion in the statistics. The typhoid bacillus is sort of exotic, and does not seem to be a very sturdy organism; it is rather a special development, and when it is thrown into a mass of liquid with other bacteria, succumbs, under contest with some other organisms. Hence, if you immerse an infinitesimal amount of typhoid culture in pure water, you at once facilitate the development of the typhoid germ; but if you introduce it into a foul liquid, it is killed off by the bacteria that are there.

There is another question often overlooked. In a city like this a large number of us have become immune, perhaps without knowing it; perhaps by being constantly exposed to the conditions without actually being contaminated by them. When there is a temporary lull in this condition,—when the epidemic prevalence diminishes,—a certain number of people grow into susceptibility and the number of immunes falls off, at which time there may be a rise in the disease. In the Philadelphia statistics you will find that a high death-rate from typhoid has often been followed by a comparatively low one, and the reason is that it has killed off a good many people who were susceptible.

In a condition like that of Philadelphia five or ten years ago, with a bad water-supply all over the city and a million people drinking it, there was a general epidemic of typhoid, and local conditions are lost in a general epidemic. After the general epidemics are diminished, the local conditions will appear; milkmens' routes will then show up which are now lost in the general statistical conditions. Many hundreds of typhoid cases have been traced to milk.

Solomon Swaab.—It appears to me that there is one phase of this subject that has not been entered into at all. As typhoid is a water-borne disease, the people of Philadelphia have for years been boiling the water by direction of the Board of Health. The city is now going to be entirely supplied with filtered water, and it seems to me that as soon as this fact is announced in the newspapers, the people will stop boiling the water immediately. It is a well-known fact that the filters take a certain time to develop to do their best work, and I think it would be well for people to continue boiling the water until they are assured that it is freed from bacteria. After the water is turned out of the slow sand filter—perhaps for two weeks after—I would say that the effluent would show the same bacterial count as the influent.

F. H. Snow.—It seems to me that the statement by Dr. Leffmann in answer to Mr. Murphy is rather a profound and unanswerable argu-

ment, and evidences the necessity of sewage treatment works as well as the purification of the water. Sewage must be purified before going into a water used subsequently for drinking, unless a water filter can be built and maintained so that it will never break down and that the introduction or by-passing of raw water into the system shall never occur.

George R. Stearns.—Mr. Murphy spoke of the temporary increase in typhoid as an immediate consequence of the extension of the filtered water system. I do not know whether he makes the claim that this increase is invariable, and I am not in a position to dispute it; but his chart or curve I understand shows such an increase in Camden when the artesian water was first introduced in that city some time ago. I have seen a similar curve showing that upon the introduction of filtered water there was an immediate falling off in typhoid fever in Frankford and vicinity.

Overconfidence in the purity of the immediate product may, as Mr. Swaab has pointed out, account for such an increase. In many of our pipes there is considerable sediment, and the opening of a valve or plug or any other cause that will create a disturbance is liable to raise that sediment and bring out in the water foreign matter which, under ordinary circumstances or without these disturbances, would possibly remain where it was. This condition is liable to occur for some time after filtered water has been turned into the pipes.

There is one point upon which I would like to have Mr. Snow express his opinion, and that is, the amount of pollution which a stream can receive without being affected. I appreciate that this presents a deep problem for solution, and perhaps it is a delicate one for him to discuss; but the relation of density of population to the flow of the stream upon which it is dependent for drainage is a subject of great interest. It is one of the chief factors involved in the amount of refinement that it is necessary to employ in the purification of sewage. As I understand it, the State Board of Health has to use its discretion as to the degree of purification for the effluent which has to be attained in individual cases, and has no exact standard to be applied to all towns throughout the State.

F. H. Snow.—Mr. Stearns has raised a very pertinent question. The policy of compulsory preservation of the purity of streams to protect the public health necessarily involves in the aggregate, in Pennsylvania as well as in other States, the expenditure of many millions of dollars finally. How much money in any given instance

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should be spent is problematical, and no general rule relative to the standard of purification to be obtained throughout the Commonwealth, regardless of local conditions, could be made in equity. Such a rule, if attempted, would have to be necessarily unjust. There are some cases where a very high standard of purification would be demanded, and the rule would be set by this standard, and in consequence work a great hardship financially on other interests where the demands of the public health might not be subserved sufficiently for the extra expense involved to secure the highest degree of purification. At present, the practice has not become extensive enough to form a basis for a fair opinion as to the amount of money the municipality is justified in spending, viewed from the standpoint of the safety to public health which such a standard vouchsafes. Consulting engineers are competent, possibly, to pass on any particular instance. If the State authorities hesitate to set a general standard of purification except in individual cases, certainly the private engineer might well hesitate to fix a standard and set it up, and to say to all others who may design works for sewage disposal that an effluent equal to the standard shall be obtained.

There is no more difficult problem involving public policy and the engineering profession than the one of what is good engineering in any town or city respecting its water-supply and sewage disposal. As I said in my written remarks, the engineer, before designing works of this character, should thoroughly diagnose the entire subject locally, and work out plans on a comprehensive basis. This involves much time and considerable outlay of money. Until the local authorities of cities and towns realize this and are willing to engage and pay for the services of a competent engineer, the progress toward a general and satisfactory common practice approaching anywhere near to what engineers know to be the best practice, will be slow at best. The public as a client of the medical profession is protected. The organization of medical men of the State for self-protection has protected the public. Likewise, the banding together of lawyers in county and State associations has worked out for the mutual benefit of the lawyer and his client. A movement has now been started at Harrisburg for an organization of the engineering profession of Pennsylvania in all its branches. Let us hope that this movement will also mutually benefit the taxpayer and the engineer.

Dr. Horn.—There are some details of interest in connection with the points brought out by Dr. Leffmann. According to the Thirty-

eighth Annual Report of the Massachusetts State Board of Health, effluents containing a large amount of suspended matter undergo more complete sedimentation, so that a sewage which is more diluted is more expensive to handle, or rather to purify to the point at which it would pass the requirements. Requirements are stated quite definitely in the Fifth Report of the British Royal Commission on Sewage Disposal, where they allow not more than thirty parts per million of suspended matter in effluents in the purification of sewage. The Massachusetts State Board of Health found that between 70 and 80 per cent. of the total suspended matter settled within a period of two to six hours, and that in waters having a large amount of suspended matter somewhat above that, and reducing in subsequent treatment the cost as well as the complications. So that the amount of waste water thrown into sewage is a significant factor in determining the methods and the cost of the subsequent treatment.

Marshall R. Pugh.—The great water consumption in the United States, with the consequent large volume and comparatively weak composition of the sewage, just referred to, has undoubtedly a most important bearing on sewage disposal. The Germans have paid a great deal of attention to the best form of sedimentation tanks, and they have found that both the design of the tank and the velocity of flow through it have the greatest influence on the attainment of good results. Careful experiments with the Cologne tank showed the value of having a sump at the inlet end of the tank, and of sloping the bed of the tank upward toward the outlet. Moreover, with a properly constructed tank it was found that while a low velocity of current caused the deposition of a greater volume of sludge, a more rapid current produced a sludge containing less moisture, but a much greater percentage of dry residue. For example, with a velocity of $\frac{1}{6}$ inch per second about 4 gallons of sludge were deposited, containing 4.4 per cent. of dry residue, while with ten times that velocity but 1.8 gallons of sludge were produced, but this amount contained about as much solid matter as did 4 gallons obtained at the low velocity.

Albert Priestman.—I should like to become better informed as to the rapidity with which deaërated water can be reaërated. The last report of the Royal Commission of England shows that about 80 per cent. of the purification of sewage is brought about by the respiratory process; that is to say, by combination with oxygen first breathed by bacteria. I believe in the rusting of iron as much heat is generated as if the same weight was burned in oxygen. The one is a

slow process, while the other is an exceedingly rapid one; and likewise in sewage purification there is a very wide difference in the time required for satisfactorily treating sewage, and this difference is largely in accordance with the rapidity or otherwise of the process of oxidation. It seems that it does not matter what name we give the particular method employed, because the problem resolves itself into what is the best and least costly method of accomplishing the oxidation of organic matter. It has been claimed that the Scott-Moncrieff nitrifying trays showed a purification of over 90 per cent. in ten minutes by the passage of sewage through nine trays, each filled with broken stone of only seven inches in depth, and the Leeds filter an 80 per cent. purification of crude sewage in three minutes, and at Hanley a high degree of purification by the passage of evenly distributed tank effluent through the first foot of filtering material occupying only one minute, while at Chorley in fine grain filters satisfactory treatment of chemical precipitation tank effluent is obtained at as high a rate as 2,500,000 gallons per acre per day. More recently it has been shown that in percolating filters the time of contact between the sewage and the filtering material is much longer than was previously thought to be the case, and we now know that considerable liquid is held in the interspaces of a filter by capillarity, so that a drop of sewage passing downward intermingles and is diluted with a larger volume which is held to the particles of broken stone, and which has been exposed to the action of the air in the filter and of aërobic bacteria. Inasmuch as we know that the process of nitrification is an exceedingly rapid one, I would like to obtain better knowledge of the rate at which water will absorb air.

Henry Leffmann.—The aëration question was studied by Leeds and Drowne, and I think their conclusions were that we cannot get much benefit from it. Water takes up a certain amount of oxygen and cannot be forced to take up and utilize any more. Possibly, something might be gained by forcing air through the water, but I doubt it. Of course, air can be ozonized and made a corrosive agent, but that resolves into another question.

I want to introduce the question of manufacturing wastes; that is going to be a great problem, for manufacturing wastes are abnormal wastes, and cannot be dealt with under ordinary sanitary conditions. Take the waste from a factory for instance. If a little dribble of sulphuric acid or other acid or iron sulphate goes into a stream, great trouble will ensue. The wastes from straw pulp works or sulphite pulp

works give a great deal of trouble. Manufacturers may yet be obliged to purify their waste and keep the streams free from pollution. In the western States one of the distilleries has succeeded in producing an inoffensive discharge; they use part of it as fertilizer and reap a revenue therefrom. Manufacturers who produce dangerous chemical wastes may be compelled to hold their wastes back and purify them in their own plants.

Marshall R. Pugh.—There were some interesting experiments made at Hamburg, which show that the oxygen dissolved by the liquid is but an insignificant part of what actually is used up in a biological filter. The gelatinous film from a mature contact bed was placed in a closed bottle provided with a mercury gage, and a known volume of oxygen admitted. Oxygen was absorbed by the filter and a diminution of pressure was registered on the gage. In a variation of this experiment a small contact bed, when empty, showed such intensely active decomposition that oxygen was forcibly drawn into the body of the bed through narrow glass tubes from a reserve bottle, causing quite a vacuum in the latter. In other words, a bed standing empty is not aërated merely by the air drawn in by the outflowing liquid. A much greater quantity is absorbed by the gelatinous film, which seems to act somewhat as does spongy platinum.

P. A. Maignen.—I think Mr. Snow has made out an excellent case for the necessity of purifying both the sewage and the water. He has made an appeal to the engineers of this Club to state their ideas on what is likely to give the highest degree of efficiency.

The first question on which I think I can throw a little light is the increased typhoid fever in Camden when the wells were first put in service. One of the reports of the New Jersey State Board of Health contains a statement by an engineer or chemist tending to prove that the water pumped up from the artesian wells did not come from the Delaware River, and to prove that this was the case he states that the well of a certain farm in Palmyra had been drained dry almost as soon as the Morris pumps were started. This would tend to show that the plane of the ground-water had been lowered, and that the contents of the Palmyra well had been drawn down into the main body of water. It is a well-established fact that typhoid fever and other water-borne diseases are more prevalent in extremely dry seasons than at any other time, because the wells become draining shafts for the whole territory around.

I well remember an example of this phenomenon. I was called upon

to investigate an epidemic of typhoid fever in military barracks near Brest in France. These barracks were situated on a plateau surrounded by some raised ground on all sides but one. The water-supply was drawn from shallow wells alongside the buildings. For a number of years there were 1100 men on the settlement and no serious trouble had been experienced until, about this time, the number of soldiers at the post was increased to 3000 or more. Three times more water was, therefore, needed, and was drawn from the wells. This had the effect, as at Camden, of lowering the level of the water in the wells and of draining the surrounding ground. There were 200 deaths in one month among the troops stationed at the barracks.

You will remember that some time ago I told you my views on the ripening of filters. The sand, when new, requires something like a whole month of work to unload itself of the germs which it originally contains in a dry state. These germs become incubated by the water passing through the sand and the mature bacteria work their way out with the filtered water. The sand bed may be said to be ripe only when these constitutional bacteria have worked their way out. The true rôle of the sand in filter-beds is to afford a starving ground for the few bacteria that may pass through the top layer.

I cannot agree with some of the previous speakers as to the contagiousness of typhoid, by personal contact. I will go further: from experiments which I have made lately, I am tempted to think that the so-called typhoid germs are not the immediate cause of typhoid fever. I have lately made some meat infusions; during the first three or four weeks, I had practically no bacilli of any kind, but I had a beautiful crop of the higher microscopic organisms or animalcules. The bacilli came into existence several weeks later. I have, therefore, some reason to suppose that it is the higher organisms, or protozoa, which come from dead organic matter or sewage, which, being taken into the alimentary canal, settle on the lining thereof, and it may be supposed that it is these higher organisms that open a port of entry for the coli bacilli and others which are ever present in the intestine. These, in passing into the blood circulation, develop a high degree of virulence. There are quite a number of bacteria in the intestine which closely resemble the typhoid bacilli. The coli bacillus is one of those, and many answer most of the tests to which the typhoid bacilli are subjected. If we assume that the lining of the intestine is injured by the higher organisms, then we may suppose that the coli and other like bacilli enter the circulation and bring about the complicated diseases

which result from drinking bad water. I present this thought as a mere theory, but it is just as good as any other theory in the absence of absolute facts.

If we examine the most recent installations for the purification of sewage, such as that of Reading, Pa., we find a number of interesting features. The sewage is screened and the coarse débris is removed and burnt. If the ideas that have been prevailing during the last few years concerning the rôle of bacteria in sewage purification were strictly correct—in other words, if the multiplication of the bacteria in the so-called septic tanks were desirable—why should we screen sewage? Should we not rather give them as much food as possible? Why should we not let all the solids go into the tank? But the fact that everybody now considers screening desirable would tend to show that such encouragement to bacterial life is not necessary. I hold, on this question of the work of bacteria in sewage purification, views that are entirely opposed to the prevailing general opinion; my notion is that bacteria should not be encouraged to multiply in the sewage, but, on the contrary, everything should be done to prevent their multiplication.

Allusion has been made to the refuse of chemical works. I, for one, would not object to such refuse if it were likely to prevent the proliferation of the bacteria. I have also very distinct views as to the desirability of preserving instead of destroying the sewage nitrogeneous matter. Some of you will no doubt remember the appeal made by Victor Hugo, in "Les Miserables," for the preservation of the fertilizing properties of sewage, and I have come to the conclusion that the recommendation of Victor Hugo ought to be carried out wherever possible; that is, we ought to try to preserve the manurial properties of sewage instead of allowing them to foul the rivers and lose themselves in the ocean.

It has been found at Reading that the slag used in the first sprinkling filters is disintegrating. In the new filters now under construction stones are used.

While the sprinkling filters have given certain results, it cannot be said that they are altogether satisfactory. The sediment which collects on the stones unloads itself from time to time and pollutes the effluent. The sediment which covers the stones becomes greasy or slimy and the water passes over it without leaving its fine suspended impurities, objectionable gases are evolved, and they create more or less nuisance in the neighborhood. Furthermore, the bacterial con-

tents of the sprinkled effluent is not sufficiently reduced to make it fit to go into water-courses without danger.

I have been struck, on visiting some of the sprinkling filters, by the fact that while they do some useful work when quite new, they, after a time, which may be a year or more, become defective, and to get good results it would be necessary to replace the whole of the filtering material every few years. The same is true of "contact beds." They work well only for a short time. The beautiful theories based upon the alternate filling and emptying of contact beds, and the pretty stories about aërobic and anaërobic bacteria in septic tanks, have received a shock of late. The trouble in all these systems lies in the fact that too much work is expected from the bacteria and from too small an area of surface. You will no doubt have seen at some country house the slop and waste water flowing out on to the ground outside the building and wending its way into a ditch. The course of this miniature sewage disposal plant is manifested by blue, black, and white deposits. These deposits are decomposed by the bacteria, the sunlight, and the air; the rain and all the elements of nature contribute to purify this refuse, and you can see that at a distance of 50 or 100 feet the effluent is clear and odorless.

With the systems now in vogue—septic tanks, contact beds, sprinkling or trickling filters, sedimentation tanks, and sand banks—there is never enough area to allow the bacteria and the elements to work out a complete purification of the sewage, and the time comes sooner or later when every part of the plant is sewage-sick. What was once a sewage nuisance has now become a sludge nuisance. We now hear of the "typhoid fly," which is supposed to charge its legs and probe with "germs" on the floating lagoons of sewage sludge, carrying the infective matter on to our food-stuffs.

The chemical treatment of sewage seems to be the most promising feature of the whole problem. It alone has resisted the test of time. It is true many systems have come and gone, but others have remained. The chief advantage of this feature is that the process of chemical purification is equal to itself every day of the year and all the time; while the mechanical appliances—septic tanks and sprinkling filters—become old and useless after a time. I understand that, in the State of New Jersey, if the sewers along the coast are so low that there is no height for a gravity sewage disposal system, the State Board of Health allows the sewage to be sent to the sea without filtration if the demand of the municipal authorities is accompanied by a promise to

disinfect the raw sewage by a germicide. This question of chemical purification is one that is not very easy. Raw sewage is more easily acted upon by chemicals than stale sewage. Of course, a large quantity of chemicals is required, owing to the presence of the solids. The chief objection to chemicals is the cost, but this should not stand in the way of experimentation; the money should be spent in that which is sure to produce results, and economies should be made in accessories.

We ought not to be satisfied with anything less than 100 per cent. efficiency.

Mr. Daniels.—I have no doubt that you have read about the experiments that have been conducted at Red Bank, N. J. The report of the New Jersey State Sewerage Commission to the legislature of 1908 contained some of the data. The experiments covered a period of about ten weeks; in this time there were treated about three million gallons of septic sewage, and it was found that the septic sewage took a large quantity of chemicals; a good deal more chlorid of lime was necessary than would have been the case had the sewage been treated before undergoing septic action.

We obtained good results by using about 10 to 12 parts per million of available chlorin, which was applied in the form of a solution made from ordinary commercial bleaching-powder. I personally mixed about 100 pounds per day in a large hogshead of water. This solution was allowed to stand until the next day, and then the clear solution was drawn off into another hogshead, from which the dose ran through a lead pipe into a little box hung on a regulating lever. This box was put on the lever because of the great fluctuation of the sewage flow. In the report of the State Sewerage Commission there are diagrams which show how the apparatus worked. We used about a hogshead of material in twenty-four hours. In my efforts to keep the dose running constantly, I was detained sometimes at the works almost night and day, and for two nights I made hourly measurements of the flow and watched the running of the bleach in addition to the regular daily routine.

I found, too, that the parts of iron apparatus which came in contact with the bleach rusted very rapidly, and for this service iron was not very good. Brass was better than iron, but lead pipe was better than either. The solution was composed of about 100 pounds of bleaching-powder to 450 gallons of water, and was therefore quite strong. We used about six or eight parts per million of chlorin on

the crude sewage we pumped out of the mains. The trickling filter effluent would require about five parts. The other day I experimented on Delaware River water and obtained quite a perceptible disinfection with two parts per million.

The cost of treatment with chlorid of lime is about $2.50 per million gallons for ordinary sewage, and it varies somewhat with the cost of bleaching-powder.

In regard to the rapid absorption of oxygen by water, it is not known just how fast water will absorb oxygen. I know from personal experience that the first amount of oxygen will go in rapidly, but there will soon be a saturated layer, which, obeying the regular law, keeps out other oxygen, and the rate of absorption is then much slower.

F. H. Snow.—What does the speaker mean by "purification?" Does it relate to the destruction of bacteria or to the removal of all impurities in the sewage?

Mr. Daniels.—As I understand it, the purification by chlorid of lime treatment is for the removal of at least the dangerous organisms. It is almost entirely impracticable in my own estimation to thoroughly and effectually sterilize sewage. About the nearest thing that can be done is to get such a degree of removal of bacteria as will make it pretty certain that the pathogens have died off first, and that remaining ones are of the harmless type. In all probability the treatment by chlorid of lime will supply a certain amount of oxygen, which will assist in oxidizing the material and will also, in doing this, assist in the chemical purification. I think the principal thing in the chlorid of lime treatment is to remove the dangerous organisms. The New Jersey State Board of Health will not allow the chlorid of lime treatment to be used alone in places where the sewage flows into small streams with insufficient water to dilute it, because the undiluted effluent from the chlorid of lime treatment will, in all probability, become putrid and cause nuisance. The question of the growth of the bacteria is a very difficult thing to answer right off; that is, it is affected by various substances. In the experiments at Red Bank I was unable by any chemical means to detect any available chlorin in the final effluent, and the organisms I found there were the organisms which were left when the chlorid of lime had ceased to act, or, in addition, those due to a very slight increase in growth after that time. The amount of time the available chlorin will remain in the solution depends a good deal on the amount and the nature of the organic matter.

George S. Webster.—At Birmingham, England, the sewage is treated at a purification plant, which, I suppose, is about as well conducted and as intelligently maintained and operated as any sewage purification plant in the world. The final effluent is clear and free from odor, but, early in 1908, as it did not meet the standard of purity fixed by the Conservancy Board of the district—although it was proved by abundant testimony of scientists that the discharge of the effluent into the river was of distinct benefit to the river—the down-stream municipalities successfully prosecuted suits for damages.

It is important that all engineers who are called upon to design sewage purification plants should have definite information as to the standard of purity they are required to meet, so as to more intelligently handle the problems which are presented.

F. H. Snow.—The standard of purity to be attained by sewage works does not depend entirely on the plant itself, although primarily the design of the plant has a great deal to do with it; but if an engineer designs a most approved plant and builds it, the effluent may be absolutely bad owing to unintelligent operation. The administration of the laws of the State operates to predetermine to quite an extent what the effluent from a given plant will be. The designing engineer employed by the town must have his own conception of what kind of a plant is necessary. His plans must then be submitted to the State Department of Health for approval. The plans may be modified or approved. Those of you who have had experience know that when an approval is given, it is accompanied by stipulations, one of which is that the plant shall be operated in an efficient manner and that the effluent therefrom shall be as satisfactory as it is possible to obtain from works of that particular type.

It is quite essential that the designing engineer should be conversant with the needs for sewage disposal works, and that he should be posted on the practice in the art throughout the country. The problem is one which has challenged the skill and ingenuity of the greatest chemists and bacteriologists and engineers and sanitarians for more than half a century, and the solution of the problem is still in its infancy. Consequently only those engineers who have made a study and have a broad view of the subject are best qualified to undertake any local problem. It is readily seen that to quite an extent the prompt action of the State officials, who are by law compelled to consider the sewage disposal plans of the town, depends upon the care and manner in which the local engineer goes at his subject, prepares his report, and lays it

before the said State authorities for consideration. The practice, which it is hoped will not become extensive, of a town council calling for bids by engineers on the preparation of plans for the sewerage system and disposal works, is not only discouraging to the engineer, but it produces other bad results. Incomplete designs are made, inexperienced men are engaged, and all kinds of difficulties ensue, and the taxpayer's money is wasted. The very best investment which a municipality can make is to employ competent engineering service. Another point which operates against the advancement of the engineering profession in popular opinion is that town engineers hold aloof from calling in the consulting engineer, who, in one, two, or three days' time, for a respectable fee, can give advice to the town engineer worth in actual saving to the taxpayer many times more than the amount of said fee. Often the fear is entertained by the town engineer that such a course would lose himself prestige among the town council and the citizens of the community. My own experience when a young man as city engineer was to the contrary. My position was strengthened and my usefulness extended by bringing into the city to my aid qualified experts, whose successful experience along the lines of their specialties was a great aid to the city I was serving. And this ability to see wherein an advantage to my client was to be gained, coupled with the courage to accept the advantage, proved to be an exhibition of an asset which resulted in the extension of my field of usefulness beyond the limits of that city. This is also true relative to large corporations. They do not hesitate, as is very well known, to command the best service when occasion requires. There is a distinct field of work for the consulting engineer which is not in opposition to the field of the local engineer, and it is to be hoped that this fact will lodge in the minds of local authorities throughout Pennsylvania with particular reference to water treatment and sewage treatment projects.

A good illustration of the point that no general State law should be passed regulating the standard of purification is afforded in the valley of the Lackawanna River. For about sixty miles of the length of this stream its banks are lined with thickly populated municipalities. In its narrow and precipitous valley lies the city of Scranton, and above and below this city, which is located about midway of the course of the river, there are cities and numerous boroughs. The Lackawanna River, though limited in watershed, always has a very considerable flow, owing to the pumpage of vast quantities of mine water from the ground. During the drier months of the year a large percentage of

the flow of the river is water pumped from the coal mines. Of course, such water is strongly acid. Bacteriological tests of the waters of the stream have been regularly made over a series of months, the samples being collected at different points in and above and below the city of Scranton. Some of these samples were taken opposite the sewer outlets, from which sewers are discharged large quantities of house and town drainage. During ordinary stages of the river the waters do not show the presence of sewage organisms. Many of the bacteria are killed by the purifying and germicidal effect of the acids in the stream. Suspended sewage matters are precipitated. It is only in freshets that the sewage pollution is revealed by a bacteriological test. So, under the local conditions obtaining in the valley, there is a natural sewage treatment plant in the river itself. Permit me to ask the question,—however, I will not answer it,—what better sewage disposal plant is wanted than this natural arrangement? The pathogenic poison is intercepted or killed under ordinary conditions. It does not reach the mouth of the Lackawanna River and flow into the Susquehanna River. Furthermore, there is no nuisance complained of up and down the Lackawanna River valley by reason of the discharge of sewage into the stream.

The time will come, perhaps, when the coal mine operations shall have been abandoned, when the original and natural condition of the Lackawanna River will be restored, provided, however, that the discharge therein of the sewage of the municipalities in its valley has been discontinued. If not, the river will be an open sewer, and a great nuisance and menace to health will have been established. Just when the conditions which now operate to prevent the nuisance will have changed sufficiently to make it necessary to begin to partially treat the sewage of the towns is not definitely known. The matter has been made the subject of reports and decrees by the Governor, Attorney-General, and the Commissioner of Health, all of which are on file in the office of the Recorder of Deeds in Lackawanna County. The policy of the State as revealed by these decrees, for the Lackawanna valley, is that all sewers to be built, from now on, shall be laid in compliance with comprehensive plans, so that when conditions shall have changed and the treatment of the sewage becomes necessary, it will be economical to add this further service to the system.

The drainage of sulphur waters from coal mines throughout the anthracite and bituminous coal fields of Pennsylvania has been very beneficial in the purification of the streams so far as sewage pollution

is concerned, and to this fact may be attributed partly the lack of sickness from water-borne diseases in mining settlements. Usually the water-supplies are brought in from the higher mountainous regions above the coal measures, and these waters are usually pure and wholesome. The extreme acidity of the streams passing the mining settlements precludes their use for any other purpose except the disposition of sewage therein from the settlements, and thus the inhabitants have been protected. If a law prohibiting coal-mine drainage into the waters of the State were enacted and enforced, it would impose a heavy financial burden on the coal-producers, and it would also impose a heavy financial burden on the municipalities whose sewage is now going into these acid streams. Most of the natural water-courses into which the mine drainage first flows are small brooks and runs, and if the acids were withdrawn or neutralized these streams would at once become open sewers, and a nuisance would be established whose abandonment would be required immediately. This is especially true of the Lackawanna River valley. The query is whether, in view of the limited financial resources of the cities and towns in this valley, and in view of the many other demands for municipal expenditures, the interests of the public health would be subserved and the public safeguard increased and the general welfare of the entire Commonwealth promoted by a compulsory regulation requiring tremendous outlay for the neutralization of acid mine drainage and the treatment of the municipal sewage in the coal districts. I leave the question with you for reflection.

I wish to add, however, that it has come to my observation, in traveling about the State, that there are instances on small watersheds where the coal operators can, by a comparatively small outlay, conduct the mine drainage below that point on the watershed where exists a dam and reservoir for the supply of water to a town distant several miles. Probably all such cases can and will be handled satisfactorily to all concerned in due process of time under existing administrative power.

I wish again to emphasize conservatism on the part of the engineering profession in attempting to fix upon any general standard of purification of sewage. Where the engineer is working out a problem, he can determine what the standard of purification shall be for a particular case, and I believe that for the present each individual case is the unit basis during the early years of the erection of sewage purification plants in Pennsylvania.

Regarding the waste in water consumption which has been mentioned, I wish to say that while there is commonly admitted to be a great deal of water wasted in American cities, nevertheless, the consumption might still be ultimately great, even if a great deal of this waste were eliminated, for where meters have been installed which have reduced the consumption 100 per cent., a rapid increase in water consumption has been noted in some cases. Public sanitation and hygiene have reduced the death-rate, and this death-rate condition has somewhat paralleled the introduction of public waterworks and drainage systems. The relation between filth and disease is of long-standing recognition, and not until the water-carriage system of taking household waste away from the community was generally established did the death-rates fall considerably. The water as a vehicle for the removal of sewage has increased the consumption. There are boroughs in Pennsylvania without sewers and without adequate means for the disposition of running water recently put into the houses in the town. So this limits the amount of water, but the moment these places finish the building of the sewer system, that moment will inside water-closets, bath-tubs, and modern plumbing facilities be installed, followed by a very material increase in consumption of water. The individual household with a moderate sized family can get along with very little water each week. The aggregation of twenty or thirty families in a building where the laundry work is done by modern machinery will, for laundry work alone, increase the consumption of water enormously. So we must charge up to our modern methods of living quite a good deal of the consumption of water, and in designing sewage disposal works, while every reasonable effort should be countenanced to avoid the waste of water consumption, the plans for the sewage treatment plant should be laid out in contemplation of a liberal per capita use of the public water-supply. Of greater practical importance in the design of a sewage disposal plant is the elimination of storm drainage from the sewer system.

Somebody observed this evening that the State Board of Health of New Jersey is requiring the use of chlorin for the disinfection of sewage. This is a surprise to me. My experience with the officials of that State in past years has been that a very liberal policy prevails. Having practised the profession in many of the States of the Union, I have had opportunities to know the sentiment of engineers, and I know it to be largely in opposition to a policy which dictates the use of any particular method, device, or material. The engineer wishes to be given

ample opportunity to work out the best there is in him and to exploit any method having merit. In other words, he wishes to have accorded to him that respectful treatment and consideration to which his experience and accomplishments in his chosen profession entitle him. The compulsory use of any one kind of treatment of sewage cannot stand long. It is to be hoped that as liberal a policy toward the engineering profession will prevail in all States as has prevailed in New Jersey thus far, and has been in vogue in Pennsylvania since the establishment of the State Department of Health.

ABSTRACT OF MINUTES OF THE CLUB.

Business Meeting, January 2, 1909.—President Spangler in the chair. One hundred and thirty members and visitors were present.

The Tellers reported that Keith F. Adamson, Arthur F. Barnes, Frederic S. Crispin, Amos C. Fisler, John S. Green, Donald Graham, Lionel F. Levy, Lloyd A. Sagendorph, and Robert E. B. Sharp were elected to junior membership; and that Werner Kaufmann was elected to associate membership.

A resolution was adopted authorizing the Board of Directors to design and adopt a suitable badge for the membership of the Engineers' Club.

The paper of the evening, "Discussion of the Strength of Beams," was presented by Mr. H. D. Hess, active member. The paper was discussed by Messrs. James Christie, H. C. Berry, Walter Loring Webb, and E. G. Perrot.

Thirtieth Annual Meeting of the Club, January 16, 1909.—President Spangler in the chair. One hundred and twenty-five members and visitors were in attendance.

The following amendments to the By-Laws were presented:

Article I, Section 7, change to read: "Honorary and Junior Members shall not be entitled to vote or to hold office, but shall enjoy all other Club privileges. Associate Members shall not be entitled to hold the office of President or Vice-President, but shall enjoy all other Club privileges, except as hereafter provided."

Article I, Section 8, add: "The total number of Associate Members of the Club at any time shall not exceed 150."

Article II, Section 2, fifth line, for "Active" read "Active or Associate."

Article II, Section 5, for "Active" read "Active or Associate."

Article IV, Section 1, add at the end: "Not more than three Associate Members may be Directors at the same time."

Article IV, Section 6, sixth paragraph, for "Active" read "Active or Associate."

Article V, Section 2, for "Active" read "Active and Associate."

Article V, Section 3, for "Active" read "Active or Associate."

Article V, Section 11, last paragraph, for "Active" read "Active and Associate."

Article VIII, for "Active" read "Active and Associate."

Proposed by:

H. W. Spangler, W. P. Dallett, Washington Devereux, Wm. Easby, Jr., Geo. T. Gwilliam, Francis Head, H. P. Cochrane, Henry H. Quimby, James Christie, F. E. Dodge, J. O. Clarke, Richard G. Develin, H. G. Perring, John T. Loomis, and Henry Hess.

It was announced that the Board of Directors had a duly signed petition recommending Washington Jones, Past President, as an Honorary Member.

The thanks of the Club were extended to Mr. Gwilliam, and on behalf of his friends in the Club, the President presented him with a watch and chain, as a recognition of his long and efficient service.

The Tellers reported the election of the following officers:

President: W. P. Dallett.
Vice-President: Philip L. Spalding.
Secretary: W. Purves Taylor.
Treasurer: H. E. Ehlers.
Directors: George T. Gwilliam, Edward S. Hutchinson, Charles F. Mebus, and A. C. Wood.

The report of the Treasurer for the fiscal year 1908 was approved.

The Annual Report of the Board of Directors for the year 1908 was approved.

President Spangler made an address on "Training in the Engineering Trades in Philadelphia."

The thanks of the Club were extended to the past officers of the year 1908.

ABSTRACT OF MINUTES OF THE BOARD OF DIRECTORS.

Regular Meeting, December 19, 1908.—Present: President Spangler Vice-Presidents Dallett, Easby, and Devereux, and Directors Clarke, Cochrane, Loomis, Hess, Christie, Head, and Dodge, and the Secretary.

The resignations of Wm. B. Brendlinger, Herbert T. Grantham, A. Saunders Morris, Robert G. Dieck, J. George Klemm, Jr., S. A. Bullock, Horatio A. Foster, Hugo L. Hund, and F. M. Campbell, were read and accepted as of December 31, 1908.

The disposition of the second mortgage bonds of the Club held by the Link Belt Company was recorded in full.

In the matter of the bond of W. H. Hansell, the Trustees of the Bond Redemption Fund were directed to purchase Certificate No. 21, bond scrip, for $50.

A communication from F. G. Myhlertz was read, relative to the committee of the Club to consider the matter of licensing engineers, architects, and builders. With this communication was a letter addressed to Mr. Myhlertz, C. E., which was referred to the Chairman of the Committee.

The use of the Club-house for the night of January 8th was extended to Company B, Battalion of Engineers.

The Secretary was instructed to place the Free Public Library of Newark, N. J., on the free list.

Special Meeting, January 6, 1909.—Present: President Spangler, Vice-Presidents Dallett and Devereux, and Directors Christie, Dodge, Cochrane, and Clarke.

The charges standing against Mr. Robley A. Warner, for the advertisement inserted by mistake in the Directory, were remitted.

The resignations of Johnson Hughes, Jr., J. E. Lord, Percy T. Osborne, J. M. Ruegenberg, S. S. Sadtler, Joseph G. Shryock, and Howard L. Yearsley were accepted as of December 31, 1908.

Seventeen members were dropped from the rolls for non-payment of dues. The request was granted that members of Company B, Battalion of Engineers, should be designated by a special mark in the 1909 Directory.

The annual report for 1908 was approved and ordered spread upon the minutes.

Messrs. J. C. Trautwine, Jr., George C. Davis, Clark Dillenbeck, Kern Dodge, S. E. Fairchild, Jr., A. M. Loudenslager, and John Meyer, were appointed a committee to submit a design for a Club badge.

Special Meeting, January 11, 1909.—Present: President Spangler, Vice-Presidents Dallett, Devereux, and Easby, and Directors Hess, Head, Quimby, Cochrane, and the Treasurer.

The reports of the Board of Trustees, of the Accountants and Auditors were presented and approved.

Amendments to the By-Laws, relative to the status of associate members, were ordered printed and sent to the membership.

It was ruled by the Board that junior members advanced to the grade of active membership shall not be entitled to vote until after the payment of the additional initiation fees.

Special Organization Meeting, January 23, 1909.—Present: President Dallett; Vice-Presidents Wm. Easby, Jr.; Directors Clarke, Cochrane, Christie, Develin, Head, Mebus, Quimby, Twining, and Wood; and the Secretary and the Treasurer.

The President appointed the following for the standing Committees for the ensuing year:

House: Wm. S. Twining, Geo. T. Gwilliam, H. P. Cochrane, A. C. Wood, and James Christie.

Meetings: J. O. Clarke, Francis Head, and A. C. Wood.

Membership: Wm. Easby, Jr., Chas. F. Mebus, and Geo. T. Gwilliam.

Finance: James Christie, Philip L. Spalding, and Richard G. Develin.

Publication: H. H. Quimby, Chas. F. Mebus, and Francis Head.

Library: Washington Devereux, H. P. Cochrane, and Edward S. Hutchinson.

Publicity: Geo. T. Gwilliam, W. Purves Taylor, and J. O. Clarke.

Advertising: H. E. Ehlers, H. P. Cochrane, and Chas. F. Mebus.

The following were then elected by the Board to serve as Tellers and auditors:

Tellers: Edwin M. Evans, Alan Corson, and Moriz Bernstein.

Alternate: George S. Cheyney, John C. Parker, and H. F. Sanville.

Auditors: W. B. Riegner, C. H. Ott, and D. Robert Yarnall.

It was ordered that the President appoint a Committee on Rules.

It was ordered that an explanation of the changes effected by the proposed amendments to the By-Laws be sent out with the notice to the members of the Club.

The resignations of L. E. Edgar, George N. Leiper, and W. T. Newcomb, active members, of Amos B. Engle and Philip B. Sadtler, junior members, and of George M. Bridgman, associate member, were accepted, to date from December 31, 1908.

The death of Mr. Frederick Stamm was announced as having occurred March 8, 1908.

Mr. Alwin F. Huch was transferred to the non-resident list of members, such change to date from January 1, 1909.

The resignation of Mr. John C. Trautwine, Jr., as Chairman of the Committee on a Club Badge was accepted. Mr. J. O. Clarke was appointed in his place.

ANNUAL REPORT OF THE BOARD OF DIRECTORS,

For the Fiscal Year 1908.

January 6, 1909.

To the Members of The Engineers' Club of Philadelphia:

The Board of Directors hereby presents its report for the year ending December 31, 1908, as follows:

Eighteen regular meetings and one special meeting of the Club were held, at which the maximum attendance was two hundred and forty-five and the average one hundred and forty-two, an increase in average attendance of fifty-eight members over 1907. The special meeting on July 31 was not included in computing the average attendance, as it was called merely to enable the tellers to report on the election of new members, and no paper was presented. Eleven regular and eleven special meetings of the Board of Directors were held.

Forty-six active, thirty junior, and nineteen associate members were elected; twenty-nine active members, one junior, and one associate member resigned; seven active members and one junior member died; sixteen active members, one junior member, and two associate members were dropped from the rolls; thirty junior members were advanced to the active grade; one junior member was advanced to the associate grade, and one associate member was advanced to the active grade.

The record of deaths is:

Howard Bain (Dec. 21, 1907), Junior Member, died August 31, 1908.
George V. Cresson (Jan. 12, 1884), Active Member, died Jan. 18, 1908.
Carl Lieb (Dec. 21, 1907), Active Member, died May 17, 1908.
Jawood Lukens (Jan. 14, 1888), Active Member, died March 10, 1908.
George F. Payne (Jan. 20, 1894), Active Member, died June 7, 1908.
Wm. H. Robinson (June 21, 1884), Active Member, died March 2, 1908.
L. Y. Schermerhorn (Jan. 16, 1892), Active Member, died April 2, 1908.
Wm. S. Vaux (May 6, 1899), Active Member, died June 23, 1908.

The summary of membership compared with the summary of December 31, 1907, is:

	1907.			1908.		
Class.	*Resident.*	*Non-Resident.*	*Total.*	*Resident.*	*Non-Resident.*	*Total*
Honorary	1	3	4	1	3	4
Active	414	104	518	442	103	545
Junior	38	9	47	38	4	42
Associate	40		40	52	2	54
	493	116	609	533	112	645

The following papers have been presented before the Club:

January 4th. First meeting in the new Club House, "Dredging Equipment of the Panama Canal." F. B. Maltby.

JANUARY 18th.	Annual Address. Review of the History of the Club.	President Henry H. Quimby.
FEBRUARY 1st.	"Engineering Problems in Road Construction."	Joseph W. Hunter.
FEBRUARY 15th.	"Recent Improvements of the Incandescent Lamp."	W. L. Wilcox.
MARCH 7th.	"The Detection of Salting in Mine Examinations."	Howard W. DuBois.
	Data on Sewage Disposal in Europe.	George R. Stearns, George S. Webster.
MARCH 21st.	"The Mallet Type of Locomotive."	Grafton Greenough.
APRIL 4th.	"Socialism as Illustrated by Papers Recently Presented to the Engineers' Club of Philadelphia."	John C. Trautwine, Jr
	"The Design of the Centering for the Main 232 feet Concrete Arch Span, Walnut Lane Bridge, Phila."	George Maurice Heller.
APRIL 18th.	"The CO_2 Engine," and "A New Development in Cross Section Paper."	Henry Hess.
MAY 2d.	"Construction Methods on Section 6, Market Street Subway, Philadelphia."	S. M. Swaab.
MAY 16th.	"Sand—Its Use and Application in the Various Industries and Processes."	W. S. Reed.
	"Notes on the Theory of Steam Condensers."	Thos. C. McBride.
JUNE 6th.	Discussion of "Notes on the Theory of Steam Condensers." "A Short Description of the Work of Elevating the Philadelphia, Baltimore & Washington R. R. Company's Tracks through the City of Wilmington, Del."	H. S. Righter.
	"Waterproofing—An Engineering Problem."	Myron H. Lewis.
SEPTEMBER 19th.	"Calibrated Speed Recorder."	Arthur B. Stitzer.
OCTOBER 3d.	Discussion of Mr. Lewis' Paper on Waterproofing.	
OCTOBER 17th.	"The Development of the Downflow Boiler."	John C. Parker.
NOVEMBER 7th.	"The Foundations for the Building for the United States Naval Experiment Station at Annapolis, Md."	Harrison W. Latta.
	"Should Engineers, Architects and Builders be Licensed?"	F. G. Mylhertz.
NOVEMBER 21st.	"Wireless Telegraphy and Telephony."	C. D. Ehret.
DECEMBER 5th.	"Engineering Features of the Athletics' Baseball Park."	Michael Monaghan.
DECEMBER 19th.	"Underground Conduit."	Paul W. England.

A meeting of the junior members was held February 29th, at the call of Mr. Henry H. Quimby, chairman of the committee appointed by the Board to

suggest the foundation of a Junior Section, and the matter was discussed and a temporary organization formed.

The Junior Section met for organization March 7th, and elected Mr. E. J. Dauner president and Mr. Chas. S. Redding secretary. Seven meetings of the Section have been held, at which the maximum attendance was thirty-five and the average twenty-one.

The following papers, some of which have been printed in "The Proceedings," were presented before the Junior Section:

April 13th.	"Long Distance Electric Transmission."	Louis S. Bruner.
May 11th.	"Experience in Operating a Diesel Engine."	Jno. S. Haug.
October 12th.	"Pyrometers for Measuring High Temperatures."	Richard P. Brown.
November 16th.	"Test of a Reinforced Concrete Building—Mushroom System."	James F. Haldeman.
December 14th.	"The Methods of Estimating Costs."	Wm. H. Gravell.

Substantial shelves have been built in the library and the books have been arranged. The library is being re-indexed by a committee under Manton E. Hibbs, chairman, which volunteered its services. As no funds were available for the purpose, the Club has not purchased any technical literature since June, 1907, but the usual periodicals have been bound. The periodicals not bound have been deposited in the University Library.

The opening of the Club-house was inaugurated by a house warming on January 11th, which is fully described on page 85 of the April "Proceedings," the attendance being about six hundred.

On October 31st a "Smoker" was held, which was attended by about three hundred members and guests, at which a very enjoyable vaudeville entertainment was given.

The returns of the election were received and thrown on the screen in the meeting-room, November 3d; about one hundred and fifty members being in attendance.

The expenses of all these functions were defrayed by individual subscriptions, and it was not necessary to draw on the treasury of the Club.

At the first meeting of the Board, held January 20, 1908, authority was given to the House Committee to take the necessary steps to furnish and open a restaurant. This action on the part of the Board was in conformity with a widely expressed view of the membership that the establishment of a restaurant would be desirable and beneficial to the Club. Immediate steps were taken by the House Committee to this end, and the restaurant was duly opened on Monday, March 2d.

An expression of opinion was solicited from the membership regarding the character of the meals and the prices to be established, resulting in approximately 250 replies being received, the majority favoring table d'hote luncheons and dinners, at prices which were duly established.

From the opening until October 12th the House Committee ran the restaurant, employing a salaried steward and other necessary employees. At this time change was made to a contract system, which is still in operation, and under the terms of which the Club pays a stipulated amount for the meals served, with a

minimum guarantee. This scheme has proved of decided financial advantage to the Club. The restaurant is patronized by about one hundred and seventy-five members.

To facilitate carrying on the restaurant additional alterations were required in the house, and these alterations, together with considerable additional equipment not originally contemplated, increased the expenditure for real estate and furnishing beyond the estimate in the last annual report. Some of these items were the erection of the treasurer's office and furnishing same, altering fourth-story room to accommodate library and secretary's office with necessary additional furniture, and the necessary restaurant and kitchen equipment.

Serious consideration has been given to making arrangements whereby wives and daughters of members can make use of the restaurant, but, up to the present time, because of the physical difficulties, it has been found impracticable. It is hoped that as soon as the necessary alterations can be made, the matter will be given definite form.

Nine sleeping-rooms have been comfortably equipped, and are receiving liberal patronage, which, it is hoped, will continue to increase.

On account of the increased duties pertaining to the operation of the house and the offices of the Secretary and the Treasurer, it was deemed wise to place a manager in charge of the house and the various offices, to give personal attention to the immediate details of the work. Mr. Chas. S. Redding was appointed to fill that position on September 15, 1908, and took up his residence in the Club-house to better enable him to fulfil these duties.

The employment of the manager involved very little additional expenditure, as the Secretary and Treasurer, having been relieved of most of the detail work, voluntarily relinquished the salaries formerly paid them.

The formation of a company of engineers among the members of the Club to become a part of the State militia was consummated, and this organization should be of much value to the Club.

The proposition of the Link Belt Company, made through its Chairman, Mr. James M. Dodge, to surrender to the Club bonds to the amount of one thousand dollars, the same to be held in trust, without interest, for the payment of the initiation fees and not more than three years' dues of such beneficiaries, elected in accordance with the By-Laws, as the Link Belt Company might select, was gladly accepted by the Board on behalf of the Club.

At an early meeting of the Board the formation of a redemption fund for the redemption of the bonds of the Club was decided upon, and Henry Leffmann, Edwin F. Smith, and Edgar Marburg were appointed trustees of the fund. All initiation fees are set apart for this purpose and provision was made for future payments to the fund. As will be seen by the report of the trustees in the financial statement, the redemption fund now amounts to $1,907.37.

The accounts of the Club were placed in the hands of a firm of public accountants on October 1st. As, according to the By-Laws, the fiscal year ends on December 31st, it has not been found possible to prepare a statement of the finances of the Club in time to insert it in this report. A separate financial report is in preparation for distribution at or before the time of the annual meeting.

Respectfully submitted,

H. W. Spangler, *President.*

H. G. Perring, *Secretary.*

FINANCIAL REPORT OF THE BOARD OF DIRECTORS,

For the Fiscal Year 1908.

January 12, 1909.

To the Members of The Engineers' Club of Philadelphia:

The Board of Directors hereby presents the financial report for the year ending December 31, 1908:

The following is the report of the Accountants and Auditors who have been employed to take charge of the books of the Club since October 1, 1908.

This report covers in one table the assets and liabilities of the Club, December 31, 1908, and in the other table the income and expenses of the Club for the year ending December 31, 1908.

STATEMENT OF ASSETS AND LIABILITIES
as of December 31, 1908.

Assets.

Cash at Girard Trust Company	$576.84	
Colonial Trust Company	1,500.00	
In office	6.78	
With George T. Gwilliam (petty cash)	13.36	
		$2,096.98
Accounts Receivable:		
Members' Ledger	$1,922.35	
Membership Committee	2.45	
Reception Committee	2.75	
Smoker Committee	5.80	
		1,933.35
Inventory of Supplies on Hand:		
Wines and liquors	$114.79	
Cigars	87.86	
Coal (estimated)	15.63	
		218.28
Property Accounts:		
Building, 1317 Spruce Street	$65,850.59	
Furniture and fixtures, house (inventory)	6,835.05	
Furniture and fixtures, restaurant (inventory)	1,173.46	
Library (Book Account)	2,071.34	
		75,930.44
Insurance:		
Perpetual on Club House	$1,782.00	
Unexpired on Furniture	7.86	
		1,789.86
Sinking Fund for Bond Redemption (Trustees' Acct.)		1,857.11
Unsold Bonds		1,400.00
Total Assets		$85,226.02

Liabilities.

Accounts Payable:		
Per Accounts Payable Ledger	$3,738.56	
Henry S. Black	489.54	
John Wanamaker	65.21	
		$4,293.31

Brought Forward		$4,293.31
Bills Payable John Wanamaker		1,000.00
Accrued Interest, First Mortgage	$1,080.00	
Second Mortgage Bonds	1,420.00	
		2,500.00
Mortgage Debit:		
First Mortgage	$40,000.00	
Second Mortgage Bonds	30,000.00	
		70,000.00
Surplus as of December 31, 1907	$8,545.25	
Inventory of Coal not in above account, Dec. 31	156.75	
	$8,702.00	
Less loss for year as per Income and Expense Account	3,080.72	
	$5,621.28	
Less Depreciation on Furniture and Fixture Account	45.68	
Surplus as of January 1, 1909	$5,575.60	
Surplus set aside for Bond Redemption	1,857.11	
Total Surplus		7,432.71
Total Liabilities		$85,226.02

STATEMENT OF EXPENSES.

For year ending December 31, 1908.

Expenses.

Salaries and Wages:		
Office Salaries to April 30, 1908	$890.38	
Secretary's Office Salaries	653.23	
Treasurer's Office Salaries	955.98	
House Wages and Salaries	2,800.13	
		$5,299.72
Expense:		
Office Expenses to April 30, 1908	$745.02	
Secretary's Office Expenses	156.38	
Treasurer's Office Expenses	533.19	
House Expense	650.65	
General Expense to April 30, 1908	66.29	
		2,151.53
Publications:		
"Proceedings" Publishing	$934.56	
Directory Publishing	559.98	
		1,494.54
Miscellaneous:		
Gas and electric light	$1.354.73	
Coal and wood to April 30, 1908	145.64	
Moving and extra cleaning	192.63	
Taxes and water rent	881.25	
Telephones	370.20	
Slides	15.15	
Insurance on furniture	43.77	
Insurance on Club-house	74.23	
Club luncheons	636.39	
Meetings	710.41	
Laundry	162.87	
		4,587.27

Brought Forward			$13,533·06
Interest on Bonds and Mortgages:			
First Mortgage		$2,160.00	
Second Mortgage Bonds		1,290.15	
			3,450.15
Club-house Business:			
Restaurant Purchases		$6,234.55	
Restaurant Wages to October 12, 1908		2,768.04	
Restaurant Supplies, etc.		698.83	
Wine Purchases		512.34	
Cigar Purchases		738.51	
		$10,952.27	
Deduct Inventory Supplies on Hand December 31, 1908:			
Wines and liquors	$114.79		
Cigars	87.86		
Coal (estimated)	15.63	218.28	10,733.99
			$27,717.20

STATEMENT OF INCOME.

For year ending December 31, 1908.

INCOME.

Dues	$13,929.05	$13,929.05
Publications:		
Advertising, Directory	$827.00	
Advertising, "Proceedings"	394.89	
Sales "Proceedings"	46.60	
		1,268.49
Miscellaneous:		
Interest on deposits		99.98
Rent of meeting-room		45.00
Rent of typewriter		5.00
Credit taken for interest on amount paid for perpetual insurance		74.23
Club-house Business:		
Restaurant sales	$7,003.10	
Wine sales	461.80	
Cigar sales	788.73	
Billiards and pool	44.63	
Lodging	916.47	
		9,214.73
Loss for year carried to Balance Sheet		3,080.72
		$27,717.20

Respectfully submitted,

GEORGE T. GWILLIAM, *Treasurer.*

The above report has been prepared by the Accountants employed by the Club. The Auditors have examined accounts taken at random, and believe that the report as set forth above is correct. The bank balances are correct.

Respectfully submitted,

W. B. RIEGNER,
H. E. EHLERS, *Auditors.*

The cash available and accounts receivable together amount to $4030.33.

Our accounts payable amount to $7793.31.

We still have on hand $1400 worth of Club bonds unsold, so that the Club owes in outstanding accounts not covered by quick assets $2362.98.

We have spent for the property, 1317 Spruce Street, and the furnishing of it and the restaurant, $72,930.44, or $2930.44 more than originally contemplated, of which about $2000 is chargeable to equipment made necessary by the establishment of the restaurant, so that our indebtedness may be considered as due to this, the difference being paid from running receipts.

Or the amount can be accounted for by the difference between the restaurant expenses and receipts, the restaurant, wine, and cigar expenses being $10,749.62, and the sales being $8253.62—a difference of $2595.99 .

The following is the report of the Trustees of the Bond Redemption Fund:

January 2, 1909.

First Annual Report of the Trustees of the Bond Redemption Fund of The Engineers' Club of Philadelphia, being a statement of business for the year 1908, submitted to the Board of Directors of the Engineers' Club.

1908.	Receipts.		
April 29.	Cash from Treasurer	$840.00	
May 20.	Cash from Treasurer	115.00	
June 11.	Cash from Treasurer	115.00	
June 30.	Interest on Deposit	2.49	
Sept. 4.	Cash from Treasurer	235.00	
Oct. 30.	Cash from Treasurer	145.00	
Dec. 10.	Cash from Treasurer	195.00	
Dec. 20.	Cash from Treasurer	130.00	
Dec. 31.	Interest on Bonds	127.50	
	Interest on Deposit	2.35	
			$1,907.34
	Disbursements.		
June 16.	Rent of Safe Deposit Box	$3.00	
June 16.	Bonds Nos. 192 and 193 (each $500.00)	1,000.00	
	Accrued interest on same	23.08	
Dec. 16.	Bond No. 20 (par)	50.00	
Dec. 18.	Bond No. 203	500.00	
	Accrued interest on same	24.15	
			1,600.23
	Balance		$307.11

Assets.

Bonds owned	$1,550.00
Held as collateral by order of Board of Directors, as per letter of President, December 14, 1908, Bonds Nos. 178 and 179 ($500.00 each)	$1,000.00

Respectfully submitted,

Henry Leffmann, Edwin F. Smith, Edgar Marburg } *Trustees.*

The above account has been examined and found to be correct. The securities are in the possession of the Trustees and the balance is in bank.

Respectfully submitted,

W. B. Riegner, H. E. Ehlers } *Auditors.*

The monthly reports of the accountants, while not complete for the months of October, November, and December, 1908, showed that our income for these months exceeded our expenses $24.17 in October, $126.31 in November, and that our expenses exceeded our income by $61.77 in December. Taking into account the items that the accountants had not yet been able to properly distribute, we may say that, with our expenses reduced to a minimum, with no betterments and no replacements, our income barely meets our expenses.

With the information gained from these three months of careful living the following estimate is made of the probable income and the necessary expenses for the year 1909, on the basis of the membership at the beginning of the year:

Income.		Expenses.	
Dues	$14,060.00	Salaries and wages	$5,356.00
Lodgings	1,500.00	Taxes and water rent	885.00
Billiards and pool	150.00	Interest	3,660.00
Cigars and wine	400.00	Gas and electric light	1,500.00
Miscellaneous	200.00	Coal and wood	225.00
		Telephone	84.00
	$16,310.00	Insurance	35.00
		Club lunches	432.00
		Meetings	700.00
		Laundry	200.00
		Gen'l and house off. exp.	2,000.00
		Pub. "Proceedings" and Directory	200.00
		Restaurant	600.00
		Wine boy	420.00
		Replacement	600.00
			$16,897.00

This estimate, which we believe is a conservative one, shows that it is necessary either that the membership be brought up to the full number allowable or that the dues should be increased. We do not believe that the latter is necessary.

The Board recommends that an increase in the number of associate members should be encouraged by an extension of the privileges of such members to the extent of granting them the right to vote, and to hold office, except the offices of President and Vice-President, while limiting their number.

An amendment has been prepared, embodying the views of the Board regarding the increase of privileges of such members, under what seem to be reasonable restrictions, and the Board urges the membership to support it.

Respectfully submitted,

H. W. Spangler, *President.*

H. G. Perring, *Secretary.*

THE ENGINEERS' CLUB OF PHILADELPHIA

1317 Spruce Street

OFFICERS FOR 1909

President

W. P. DALLETT

Vice-Presidents

Term Expires 1910	*Term Expires 1912*	*Term Expires 1911*
WASHINGTON DEVEREUX	PHILIP L. SPALDING	WM. EASBY, JR.

Secretary

W. P. TAYLOR

Treasurer

H. E. EHLERS

Directors

Term Expires 1910	*Term Expires 1911*	*Term Expires 1912*
J. O. CLARKE	JAMES CHRISTIE	GEO. T. GWILLIAM
W. S. TWINING	HENRY HESS	EDW'D S. HUTCHINSON
FRANCIS HEAD	H. P. COCHRANE	CHARLES F. MEBUS
HENRY H. QUIMBY	RICHARD G. DEVELIN	A. C. WOOD

STANDING COMMITTEES OF BOARD OF DIRECTORS

House—W. S. Twining, Geo. T. Gwilliam, H. P. Cochrane, A. C. Wood, James Christie.

Finance—James Christie, Philip L. Spalding, Richard G. Develin.

Membership—Wm. Easby, Jr., Chas. F. Mebus, Geo. T. Gwilliam.

Publication—H. H. Quimby, Chas. F. Mebus, Francis Head.

Meetings—J. O. Clarke, Francis Head, A. C. Wood.

Library—Washington Devereux, H. P. Cochrane, Edw'd S. Hutchinson.

Publicity—George T. Gwilliam, W. P. Taylor, J. O. Clarke.

Advertising—H. E. Ehlers, H. P. Cochrane, Chas. F. Mebus.

MEETINGS

Annual Meeting—3d Saturday of January, at 8.15 P.M.

Stated Meetings—1st and 3d Saturdays of each month, at 8.15 P.M., except between the fourteenth days of June and September.

Business Meetings—When required by the Constitution or By-Laws, when ordered by the President or the Board of Directors, or on the written request of five Active or Associate Members of the Club.

The Board of Directors meets on the 3d Saturday of each month, except July and August.

PROCEEDINGS

OF

THE ENGINEERS' CLUB

OF PHILADELPHIA.

ORGANIZED DECEMBER 17, 1877. INCORPORATED JUNE 9, 1892.

NOTE.—The Club, as a body, is not responsible for the statements and opinions advanced in its publications.

Vol. XXVI. APRIL, 1909. No. 2

PAPER NO. 1067.

THE ENGINEERING FEATURES OF THE ATHLETICS' BASEBALL PARK.

MICHAEL MONAGHAN.

(Active Member.)

Read December 5, 1908.

THE new home of the Athletics' Baseball Club, which occupies the north side of Lehigh Avenue from Twentieth to Twenty-first Street, marks a new era for professional sport. The grounds, which extend 481 feet 3 inches on Lehigh Avenue and 520 feet on Twentieth Street and Twenty-first Street, represent an investment, by Mr. Benjamin F. Shibe, of about $500,000 for real estate and improvements. The stands seat 23,000, with standing-room, exclusive of aisles and field, for half as many more.

The main grand stand, which contains 10,000 reserved seats, forms an "L" on Lehigh Avenue and Twenty-first Street. The building is in the French Rennaisance style, and is of red brick with terra-cotta columns, arches, cornice, etc., the color of Indiana limestone.

The entrances for grand stand and bleachers are all located in and about the tower of the grand stand at Twenty-first Street and Lehigh Avenue. A mezzanine passage, connecting these entrances with the executive offices, makes possible a direct, unobserved supervision of the sale of all tickets by the manager. A passage beneath the grand stand connects this entrance with the bleachers. A stairway, 23 feet

in width, leads directly to the main floor of the grand stand. There are ten large exits from the stands and field.

The grand stand contains two sets of locker-rooms, shower-baths, and lounging-rooms for the players, stores, a restaurant, and the executive offices.

The bleachers, one containing a garage and the other a storage wareroom, complete the two sides of the square. The rest of the inclosure is formed by a reinforced concrete fence, 11 feet high.

A concrete rail, 2 feet 9 inches high, extends in front of all stands, and serves as a boundary for the spectators; but is not high enough to prevent the easy exit of the crowds. Gates are provided at the aisles for occasional women visitors.

Fig. 1.

Fig. 1 shows the exterior of the stands and bleachers. The bleachers, main floor, and stairs of the grand stand are of reinforced concrete. The upper floor and roof of the grand stand are steel, cantilevered trusses. Wood is used as little as possible.

Fig. 2 shows a section through the grand stand. The roof is slag on plank, the slope being about 1 to $3\frac{3}{4}$, which is about as steep as was thought well to use with slag, on account of the running of the tar in hot weather. The slope of the main truss and of the first floor are such that a point on the ground 25 feet back of home plate, as well as an average high ball, can be seen from the back seats.

Structural Steel.

The location of the main column was determined by assuming an approximate dead load over the whole truss and a live load of 120

pounds per square foot on the cantilever arm only. The column was then shifted to give zero reaction at the anchor column. This gave an anchor arm of about 46 feet and a cantilever arm of 30 feet. Later, a more accurate dead load, the application of a vertical wind load of 20 pounds on the cantilever of the main truss, and of 30 pounds on the cantilever of the roof truss, gave an uplift on the anchor column of 31,000 pounds for the worst case. As the dead load carried by this

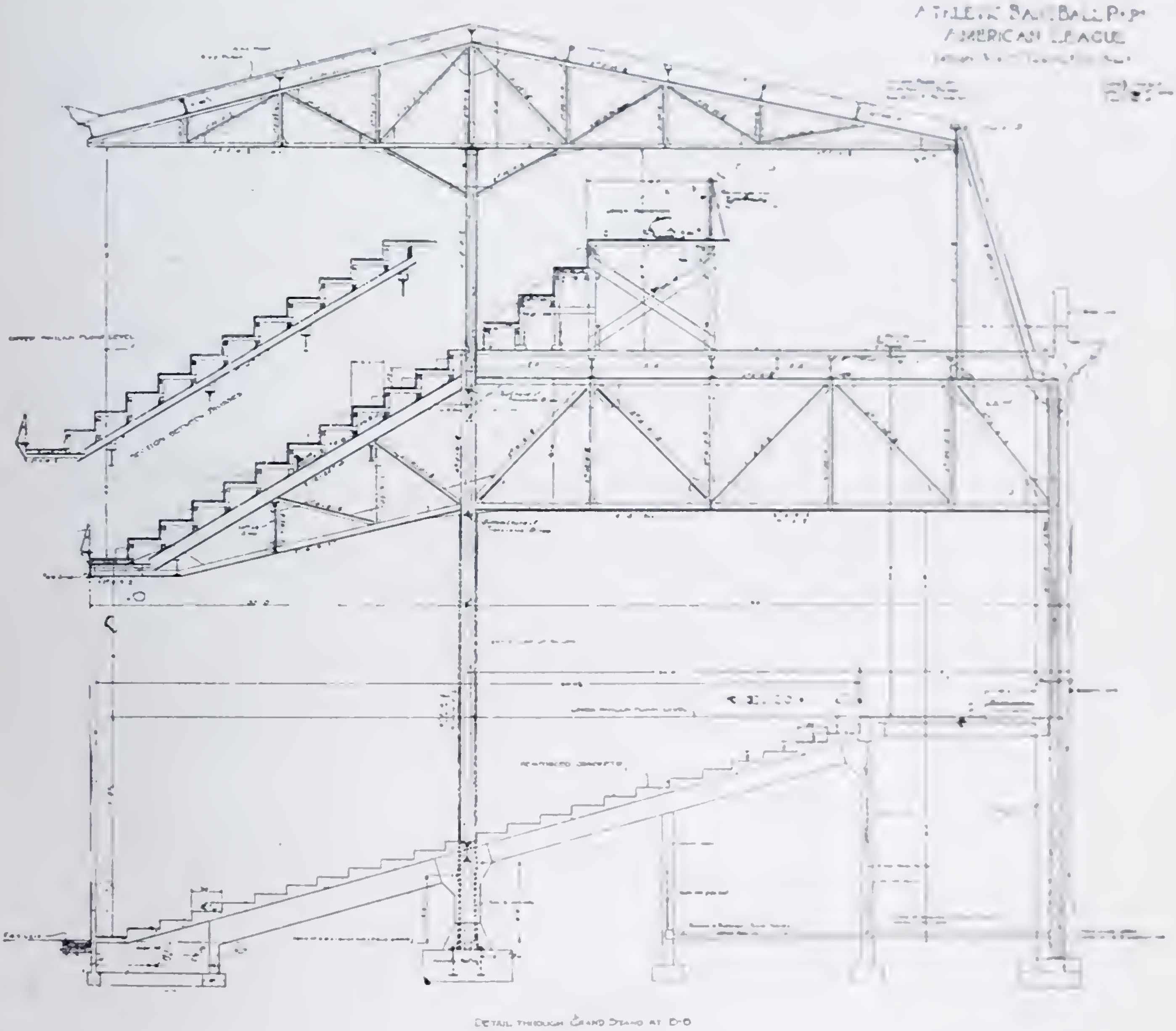

Fig. 2.

column is 93,000 pounds, the location was maintained. This gives a factor of safety of three.

The trusses and columns are spaced 25 feet center to center transversely. This is an arbitrary assumption, the object being to make the spacing as great as possible without causing the use of extravagant secondary members. As the distance center to center of the trusses increases, the difficulty of bracing the lower chord, which is in com-

pression for live load and wind load on cantilever, becomes much greater.

The depth of the main truss, 10 feet 6 inches, without projecting plates, was determined by the maximum shipping height allowed by the tunnels and bridges necessary to be passed in order to permit free competition among the bidders. Our first preliminary design was based on a truss with a straight lower chord. The truss was about 15 feet 6 inches deep. This gave less compression in the lower chord and simpler connections at both ends of the cantilever. The diagonals in compression were too long for economy, and the reduction in weight did not balance the added cost of erection for the deeper truss, which would have to be shipped loose. In the design adopted the anchor arm of the main truss, the cantilever of the main truss, and the whole of the roof truss were each shipped in one piece.

As the building is exposed to the wind to an unusual degree, the whole structure was thoroughly braced to form one solid unit. To prevent swaying in the direction of the trusses, the roof truss is stiffened at the forward column by two deep knee braces, and at the rear by a large gusset plate and two members which form a triangle and connect with the lower column and intermediate panel point of the main truss. The rear column, carrying the main truss, is embedded in the brick wall, which is here two feet thick, for architectural effect. The connection of the main truss with the main forward column, which consists of a web plate, four angles, and four cover plates, is made very rigid by letting the angles of the column continue through to the top chord and form an integral part of the truss. The large gusset plates of both chords are shop-riveted to the column. No knee brace was used at this point, on account of the depth of the truss, the stiffness of the connections, and the ambiguity of stresses, which would result from deflection of the cantilever. This column is anchored to a heavy footing and incased for a length of 8 feet in the reinforced concrete work.

In investigating the main column for bending, a horizontal wind load of 20 pounds per square foot was assumed on the vertical projection of the roof truss and the steps of the main truss. Two-thirds of the moment was assumed to be carried by this column. The resultant stresses due to bending proved to be somewhat greater than for direct loading. For combined, direct load, and bending, therefore, the direct load would be more than doubled; but as one flange of the column would be in tension, a somewhat higher unit stress in compression was

allowed. To prevent swaying in a vertical plane, transverse to the trusses, deep lattice girders were used. The roof truss has a girder 9 feet deep at the column, two 6 feet deep at intermediate panel points, and one 2 feet deep at the rear. This last is stiffened laterally by a channel to carry the thrust of the wind on the mansard roof. They all serve as purlins and brace the lower chord, which is in compression. The main truss is braced by a girder 10 feet deep at the column, the wall at the rear, and a girder 4 feet deep at a panel point of the cantilever. This last stiffens the lower chord, which is in compression. The lower chord of the anchor arm is stiffened by means of a continuous 8-inch I beam.

The design of the secondary members, where the span is so great and the load so heavy, is a very important question. For the roof purlins, 12-inch channels sufficed. The horizontal portion of the main floor consists of 18-inch I beams, 9 feet 5 inches center to center, carrying a 4-inch plank floor. The method of carrying the steps on the cantilever was a matter of some difficulty.

In the stands for the Philadelphia Ball Park, at Fifteenth and Huntingdon Streets, a channel is used to form each riser. As, however, our risers are 18 inches, an I beam or a lattice beam would be needed to carry out the same scheme. The I beam would be nearly four times the required strength and the lattice beams very expensive. Moreover, the connections to the slanting upper chord would be difficult and costly. The risers were, therefore, carried on wooden joists, fastened by bent angles to the top chord of the truss and to two intermediate 7-inch I beams, 8 feet 4 inches center to center, which are in turn supported on I beams and the lattice girders used as bracing. The resulting connections are extremely simple and the weight small. As the load is likely to move horizontally, in a body, these intermediate 7-inch I beams, parallel with the upper chord, are tied up to the columns by means of diagonal rods; thus relieving the cross-girders of any transverse strain.

Owing to the general plan of the building, which forms an L, little fear was entertained that the trusses would sway in a horizontal plane. However, as the cost was slight, one panel in each wing was braced with 1-inch rods in the upper and lower chords of the trusses.

Reinforced Concrete Work.

As mentioned above, the main floor, stairs, and dome of the grand stand, the bleachers, the fence, the railings in front of grand

stand and bleachers, as well as all footings are of reinforced concrete.

The main floor of the grand stand offered an unusual opportunity for the economical arrangement of columns, as the space under the slope is of no value. The only governing conditions are the steel columns, 25 feet center to center, the foot of the slope, and the line of columns along the top of the slope; the plan adopted consists of steps with 30-inch tread and 8½-inch rise, carried on a slab of 4½ inches in minimum thickness, spanning between beams 12 feet 6 inches center to center. The seats are to be a form of theater chair. Each line of beams is carried on a row of columns. No girders are used in the typical construction. The number of columns in each row is such that the combined cost of concrete, steel, forms, and excavations is a minimum, for beams, columns, and footings, allowance being made for an increase of cost, as the number of units increases.

As the slab is reinforced in the direction of the steps, advantage is taken of the full area of the step to increase the effective depth of the slab. As the building laws require the minimum thickness in inches of a slab to be 0.6 times the span in feet, the slab would need to be 7½ inches thick. To avoid this, the steel was concentrated near the deeper portion of the step; ¼-inch round rods, 12 inches center to center, were run at right angles to these to care for the shrinkage and carry the load on the shallower parts. As the concrete in the step is isolated more than in an ordinary slab, the usual extreme fiber stress of 600 pounds per square inch was reduced to about 500 pounds. The concrete for the beams, slab, and steps was poured at one time, thus securing the economy of the T-beam. From the point where the bottom of the beam intersects grade to the lowest step, the slab is carried on a 6-inch wall, running below frost. This avoids any uplifts on the beam or slab, due to frost.

For the promenade at the top of the slope, the panels are nearly square. An investigation showed that the quantities of steel and concrete were slightly greater for a slab 12 feet 6 inches by 14 feet, reinforced in both directions, than would be required by the use of an intermediate beam, a girder, and a slab with single reinforcement. As, however, the space under this portion is to be used for stores and club-rooms, and as the forms can be used but twice, the square panel was adopted.

The design of the bleachers offered somewhat greater difficulties. It was at first considered desirable to let the concrete steps act as

seats. This would increase the number of patrons of the comfortable grand stand and do away with the first cost and repair of seats. But as the required seating capacity necessitated 42 rows of seats, the height of the bleachers, using 18-inch risers, would be 63 feet. The columns at once became the governing feature. As a compromise, the use of 2-inch by 8-inch plank seats on 2-inch by 3-inch sleepers was suggested. This reduced the height and the dead load, but did not do away with the necessity of bracing the columns and of fireproofing the bracing. The first of these plans has been used at the Harvard and the Syracuse stadiums. In the former, steps of separately molded concrete were carried on steel I beams. The long concrete columns were braced by a steel framework. The speed required in construction

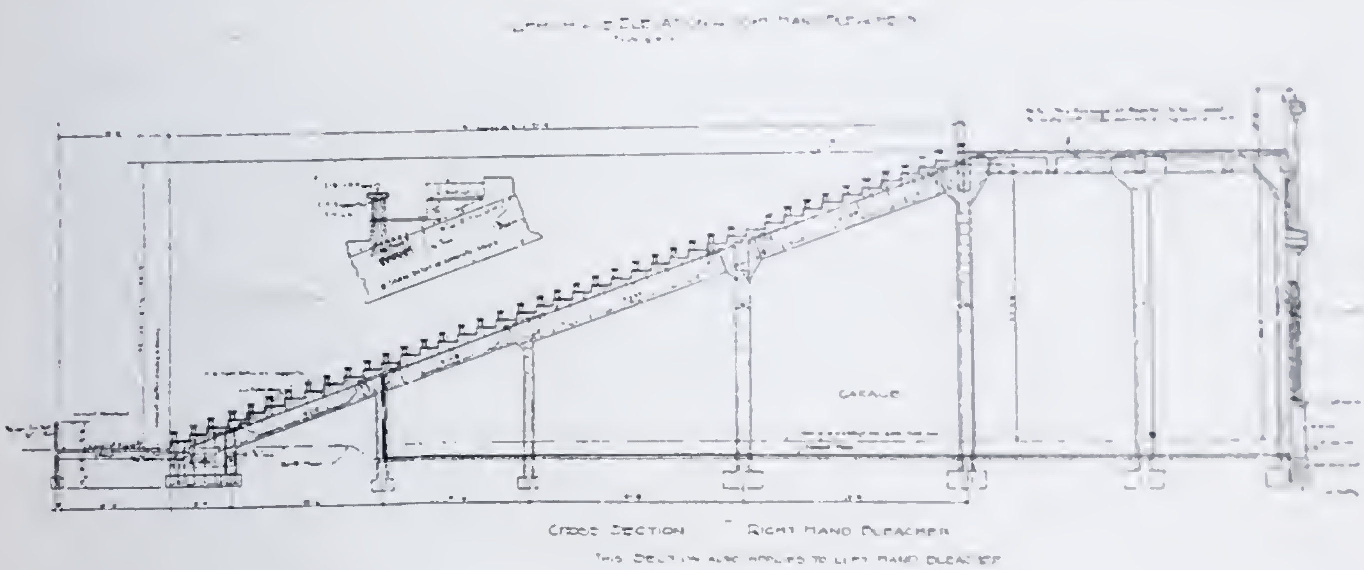

Fig. 3.

and the difficulty of making neat joints forbade our using separately molded steps. Moreover, the steel work would have to be fireproofed, as one bleacher is to be a fireproof warehouse, and the other a garage.

In the Syracuse stadium the slope of the ground conformed to that of the steps, the columns were very short, and the dead load of less consequence. The steps were poured in place solid, as in this grand stand; no attempt being made to form steps in the under surface of the slab. The slope was, however, so great that the beams were poured first and notches left for the steps.

As the dead load was, in this case, a serious matter, and as the forms could be used twice, a design and estimate were prepared on the basis of making each riser a beam, 8 inches wide, carrying a 3-inch slab for the tread. The cost was excessive, and the following scheme was adopted.

Steps 7½-inch rise and 21-inch tread were found to give an excellent view of the field; 2-inch by 8-inch yellow pine plank, supported on special castings 3 feet center to center, formed the seats, which are clean, comfortable, and easily taken care of. The castings which have lugs, to which the temporary boards for the riser forms are bolted, are nailed to the forms before any concrete is placed. This not only gives a rigid support for the seats and avoids all drilling, but also affords an easy and cheap method of maintaining the riser forms true to line

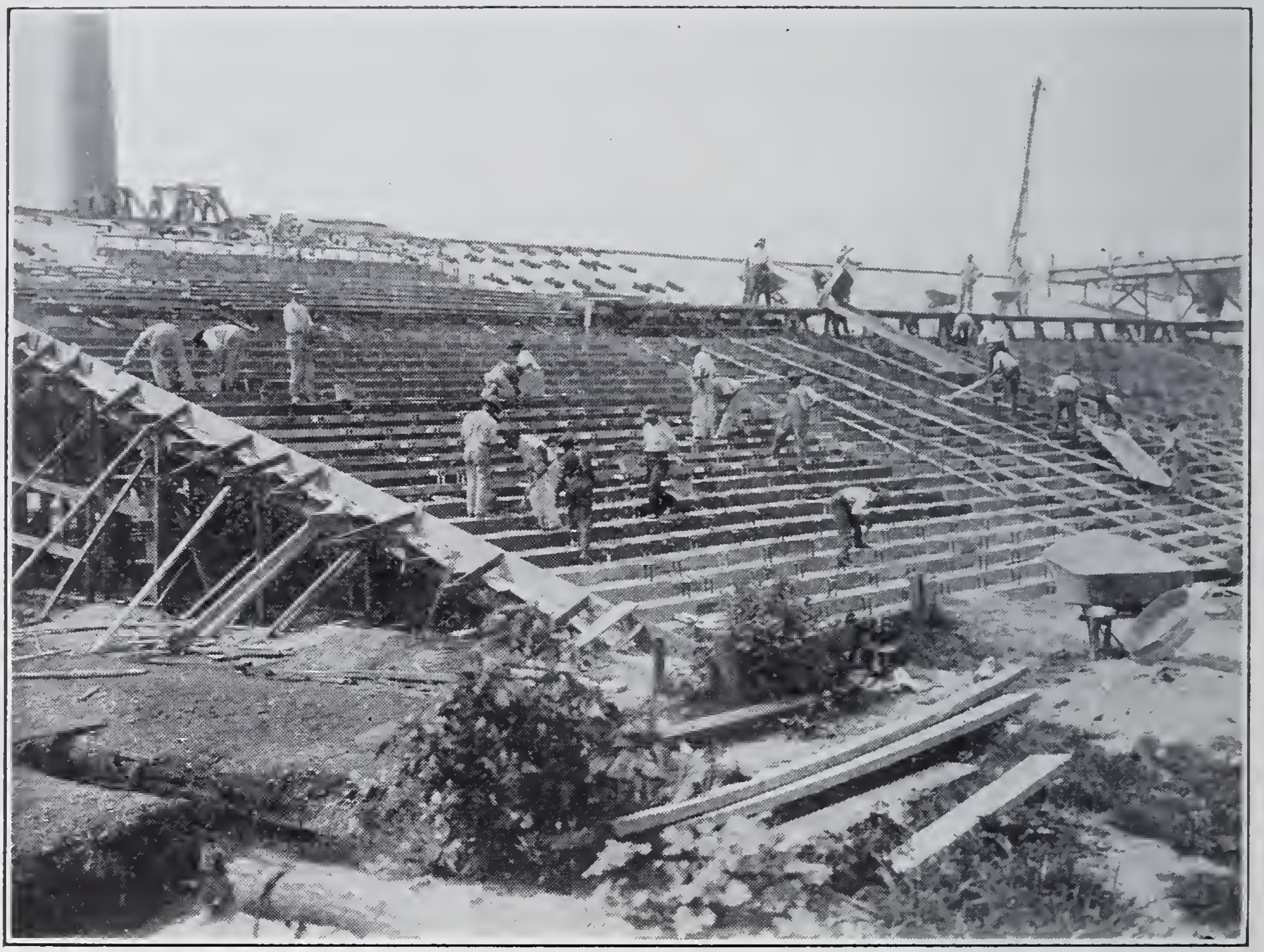

Fig. 4.

while concreting. As there are over 7000 of these castings, the unit cost was very low.

The minimum thickness of slab for the bleachers is 3 inches. The beams are 10 feet center to center. The construction differs from that of the grand stand in that girders are here used to lessen the number of columns, because the room below is of value. As the columns are very long and the loads comparatively light, our usual practice of restricting the unsupported length of columns to fifteen times the least side, and using 500 pounds per square inch in compression, was modified. The

longest column is 27 feet in the clear and 16 inches square, giving a ratio of about 20 to 1. The unit stress was reduced proportionately and twice the usual longitudinal reinforcement used.

Great care was exercised in making the forms and pouring the columns, and no trouble was experienced from bursting of forms or from voids, although the whole was poured from the top. The total fall was about 30 feet.

The concrete for the bleachers was poured in the following manner. The mixer was placed near the foot of the slope and about midway of the length. The material, which was delivered by teams, was charged into the mixer by means of an automatic dumping bucket, arranged to measure the ingredients. A standard bucket hoist raised the mixed concrete to three successive levels as the work progressed. A scaffold connected the hoist with runways on the slope, and from these runways the concrete was deposited at the level required by means of wooden chutes. The steel, the castings for seats, and the riser boards were in place before any concrete was placed except in the columns. The operation of pouring girders, beams, and slab was, therefore, continuous. The forms were used again on the other bleacher, which, though longer, has the same slope and forms the same angle with the building line.

The construction of the main floor of the grand stand was carried out in the above manner, except that the concrete was poured from two levels instead of three.

The Dome.

The dome on the grand stand at the corner of Twenty-first Street and Lehigh Avenue is approximately 20 feet in outside diameter. It is composed of cinder concrete reinforced with round rods. No structural framing was used. About twice as much steel was used as was called for by the analysis. The cost of the steel is insignificant, the stiffer steel maintains its position better, and the factor of uncertainty in all arch and dome calculations is greatly reduced. A wind load of 30 pounds per square foot was assumed normal to the surface.

The theory followed in the design is that found in Prof. Green's book on "Elastic Arches." The assumptions are that there is no pressure at the crown, and that there is a varying outward thrust due to horizontal forces tangent to the curve and resisted by the tension in the horizontal rods. The bending moment, where the resultant pressure passes outside the middle third, is resisted by vertical rods.

The whole is well anchored to the tower walls. As the greatest pressure on the concrete is about 200 pounds per square inch, cinder concrete was used.

The Fence.

It was originally intended to inclose the field with a reinforced concrete fence, 8 feet high. The posts were to be molded flat and stored until seasoned. The slab was to be $2\frac{1}{2}$ inches, plastered on a metal

Fig. 5.

lath with as large a moment of inertia as possible. When, however, the height was increased to 11 feet, the difficulty of preventing overturning, and the weight of the posts made this scheme impracticable.

The design adopted consists, as shown in Fig. 5, of a slab and substantial buttresses, formed and poured in place. It was not considered advisable to make the slab less than 6 inches thick, on account of the difficulty of pouring and puddling the concrete.

The fence was designed to resist a wind load of 20 pounds per square

foot. The factor of safety against overturning is about one and one-half, when the resistance of the earth is neglected.

The forms were removed at the end of twenty-four to forty-eight hours, depending on the temperature, and the surface floated before it had become very hard. Care was taken in puddling to keep the stones from the faces. The concrete was mixed by hand and raised in small buckets. An expansion joint was made at every third pilaster, that is, every 48 feet, to prevent bulging in warm weather. The reinforcement is sufficient to prevent cracking due to shrinkage. The section between expansion joints was poured at one time. The forms were used fourteen times.

The work was designed and constructed by the Wm. Steele and Sons Company, under the general supervision of Mr. J. M. Steele. Those more intimately connected with the details are Thomas Jamieson, C. E. McParland, C. H. Cramp, C. F. Gross, E. A. Steele, and M. Monaghan.

Credit is due the firm of Sax and Abbott for some suggestions on the design of the steel work. The steel work was constructed by Belmont Iron Works.

PAPER No. 1068.

LATERAL STRENGTH OF BEAMS.

H. D. HESS.
(Active Member.)

Read January 2, 1909.

It has been generally noted in hand-books of structural materials, and not so frequently in text-books upon mechanics of materials, that in designing or selecting beams due consideration should be given to their lateral strength. The former give rules, with, however, little or no explanation as to why those rules apply, while the latter are even more reticent upon this subject. A. E. Guy made a series of tests on rectangular wooden beams, and a series of articles describing them was published in the "American Machinist" in 1901.

Bridge and structural specifications avoid the reduction of stress in compression flanges by limiting the unsupported flange length to from 12 to 20 times the flange width. In some classes of work, particularly cranes, long lengths of beams and girders, unsupported laterally, cannot be avoided. In the "Pencoyd Hand Book" it is stated that experiments indicate a reduction of about one-third of the normal modulus of rupture when the length of the beam becomes 80 times its flange width. A table is given in which the full load of fiber-stress of 16,000 pounds per square inch is permitted on a beam whose length is 20 flange widths, and the load then uniformly reduced as the ratio of length to flange width increases, until in a beam whose span is 70 times its flange width but one-half the normal load is allowed, corresponding to a fiber-stress of 8000 pounds per square inch. The Carnegie hand-book suggests the same reduction of loads, but does not explain its method of reaching these figures.

The Cambria hand-book deduces its allowable working stresses by the column formula:

$$p = \frac{18{,}000}{1 + \dfrac{l^2}{3000\, b^2}} = \frac{18{,}000}{1 + \dfrac{1}{36000} \times \left(\dfrac{l}{r}\right)^2}$$

This column formula considers a piece subjected to a load applied along its axis, and assumes failure by combined bending and direct stress.

In the compression flange the flange force may be assumed as acting along the axis of the flange. In a simple beam supported at the ends and loaded uniformly or centrally this flange force increases from zero at the supports to a maximum value at the center of the span. It,

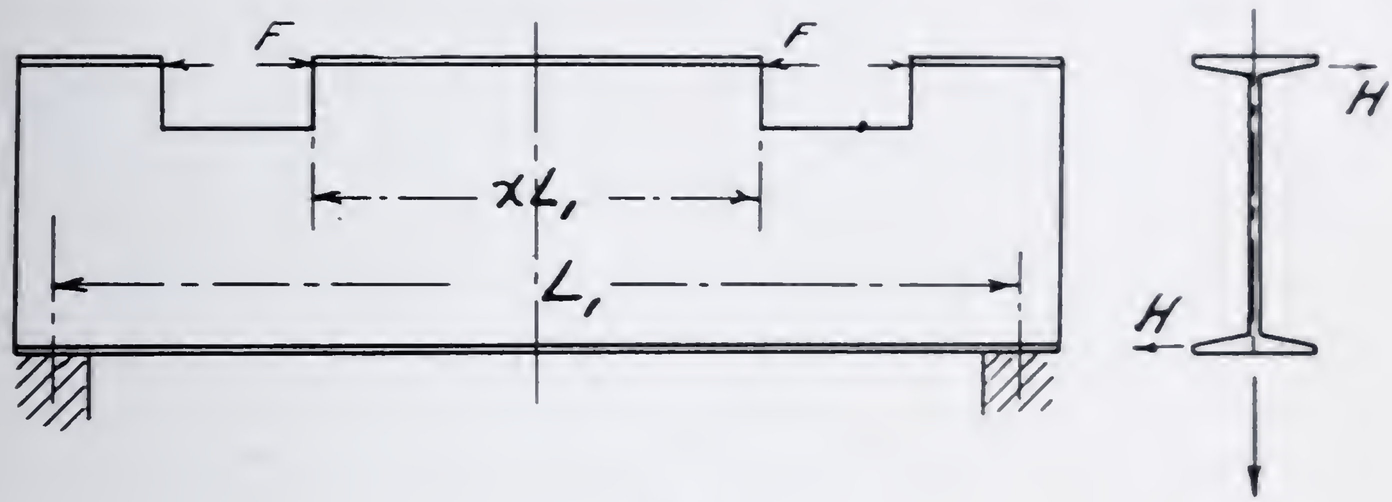

Fig. 1.

therefore, seems unsatisfactory to treat the entire length of the compression flange as a column.

The following treatment is suggested for this case. Imagine the beam, Fig. 1, cut and the forces "F" replacing the horizontal flange forces to maintain equilibrium in the beam. The forces "F" acting

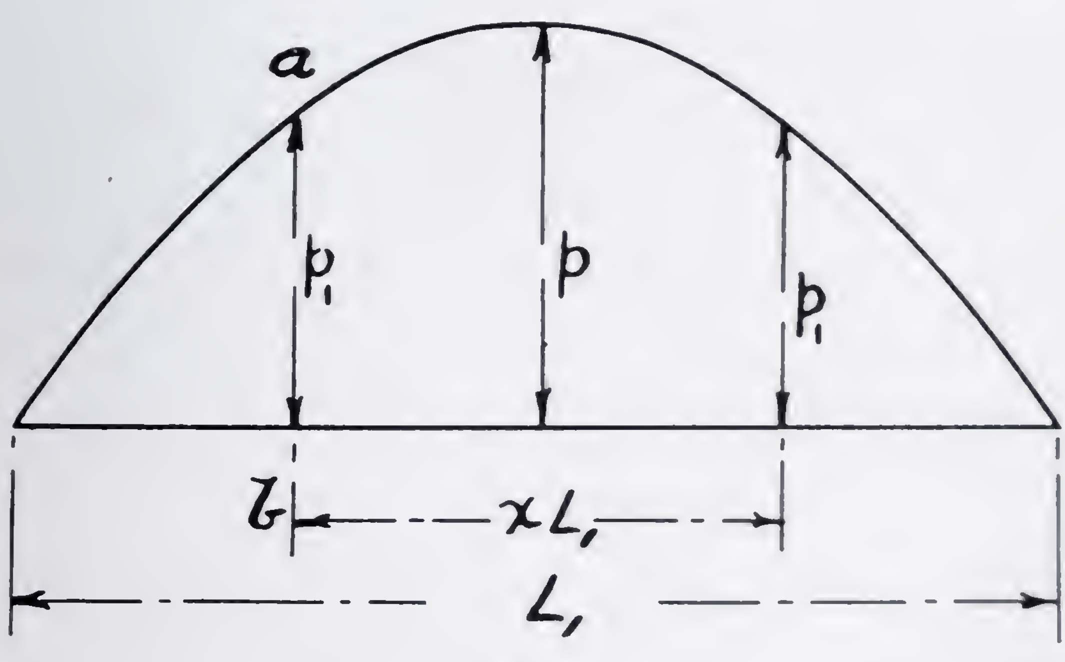

Fig. 2.

upon this compression flange may be considered similarly to the load acting axially upon a column.

If, as is usually the case, the flange is shallow compared with the depth of the beam, the force "F" will be proportional to the extreme

fiber-stress at the section, and both depend upon the character of the load and the distance $\frac{xL_1}{2}$. In the case of a beam uniformly loaded the extreme fiber-stresses will vary as the ordinates of a parabola. (Fig. 2.) From the properties of a parabola:

$$p_1 = p\,(1 - x^2) \tag{1}$$

p_1 is now considered as the force in pounds per square inch acting on the compression flange and tending to buckle a length of flange equal to xL_1.

The probable stress at the center of the span due to this stress p_1 is given by the usual column formula:

$$p_1 = \frac{p_c}{1 + k\left(\frac{l}{r}\right)^2} \tag{2}$$

here p_c = maximum stress in column due to buckling action.
p_1 = extreme fiber-stress at any section "ab."
k = constant depending upon the formula used, section, material, etc.
l = length of column considered.
r = radius of gyration of flange about axis at right angles to flange face.

It is now desired to find that length of column xL_1 which, when acted on by the corresponding stress p_1, will produce a maximum increase in the fiber-stress at the center of the span, or $p_c - p_1$ to be a maximum.

From formula (2) we have:

$$p_1 + p_1k\left(\frac{l}{r}\right)^2 = p_c$$

and

$$p_c - p_1 = p_1k\left(\frac{l}{r}\right)^2 \tag{3}$$

Combining 1 and 3, we have:

$$p_c - p_1 = p(1 - x^2)\,k\left(\frac{l}{r}\right)^2$$

and since $l = xL_1$

$$p_c - p_1 = kp(1 - x^2)\left(\frac{xL_1}{r}\right)^2$$

$$p_c - p_1 = kp\left(\frac{L_1}{r}\right)^2(x^2 - x^4) \tag{4}$$

from which:

$$\frac{p_c - p_1}{dx} = 0 = 2kp\left(\frac{L_1}{r}\right)^2 x - 4kp\left(\frac{L_1}{r}\right)^2 x^3$$

and

$$x = \sqrt{\tfrac{1}{2}} = 0.707 + \qquad (5)$$

The total maximum fiber-stress at the middle of the span due to combined bending and buckling becomes:

$$p_T = p_c - p_1 + p$$

$$p_T = kp(x^2 - x^4)\left(\frac{L_1}{r}\right)^2 + p$$

Substituting for x its value, 0.707:

$$p_T = \tfrac{1}{4}kp\left(\frac{L_1}{r}\right)^2 + p \qquad (6)$$

from which:

$$\frac{p_T}{p} = 1 + \tfrac{1}{4}k\left(\frac{L_1}{r}\right)^2 \qquad (7)$$

If it is desired to use the flange width instead of "r," equation (7) can be written:

$$\frac{p_T}{p} = 1 + 3k\left(\frac{L_1}{b}\right)^2 \qquad (8)$$

Thus far it has been assumed that no lateral stiffness was due to the tension flange. The buckling action may be assumed as inducing a horizontal force, "H," acting on the compression flange, and provided the web is stiff enough it will by torsion induce an equal and opposite force in the tension flange. Beams failing laterally show this twisting The greatest effect of the tension flange would be to carry one-half of this lateral load, *i. e.*, reduce the deflection and resulting increase in stress to one-half that given by formula (4), making formula (7):

$$\frac{p_T}{p} = 1 + \tfrac{1}{8}k\left(\frac{L_1}{r}\right)^2$$

and formula (8):

$$\frac{p_T}{p} = 1 + 1.5k\left(\frac{L_1}{b}\right)^2$$

In a similar manner the formulæ for other beams and loadings may be determined.

For a simple beam with a central load, and a cantilever beam with the load at the end $x = \frac{2}{3}$:

$$\frac{p_T}{p} = 1 + \frac{4}{27}k\left(\frac{L_1}{r}\right)^2 \qquad \text{or} \qquad \frac{p_T}{p} = 1 + \frac{48}{27}k\left(\frac{L_1}{b}\right)^2$$

If the tension flange is assumed as fully reinforcing the compression flange, then $\frac{4}{27}$ and $\frac{48}{27}$ become $\frac{2}{27}$ and $\frac{24}{27}$ respectively.

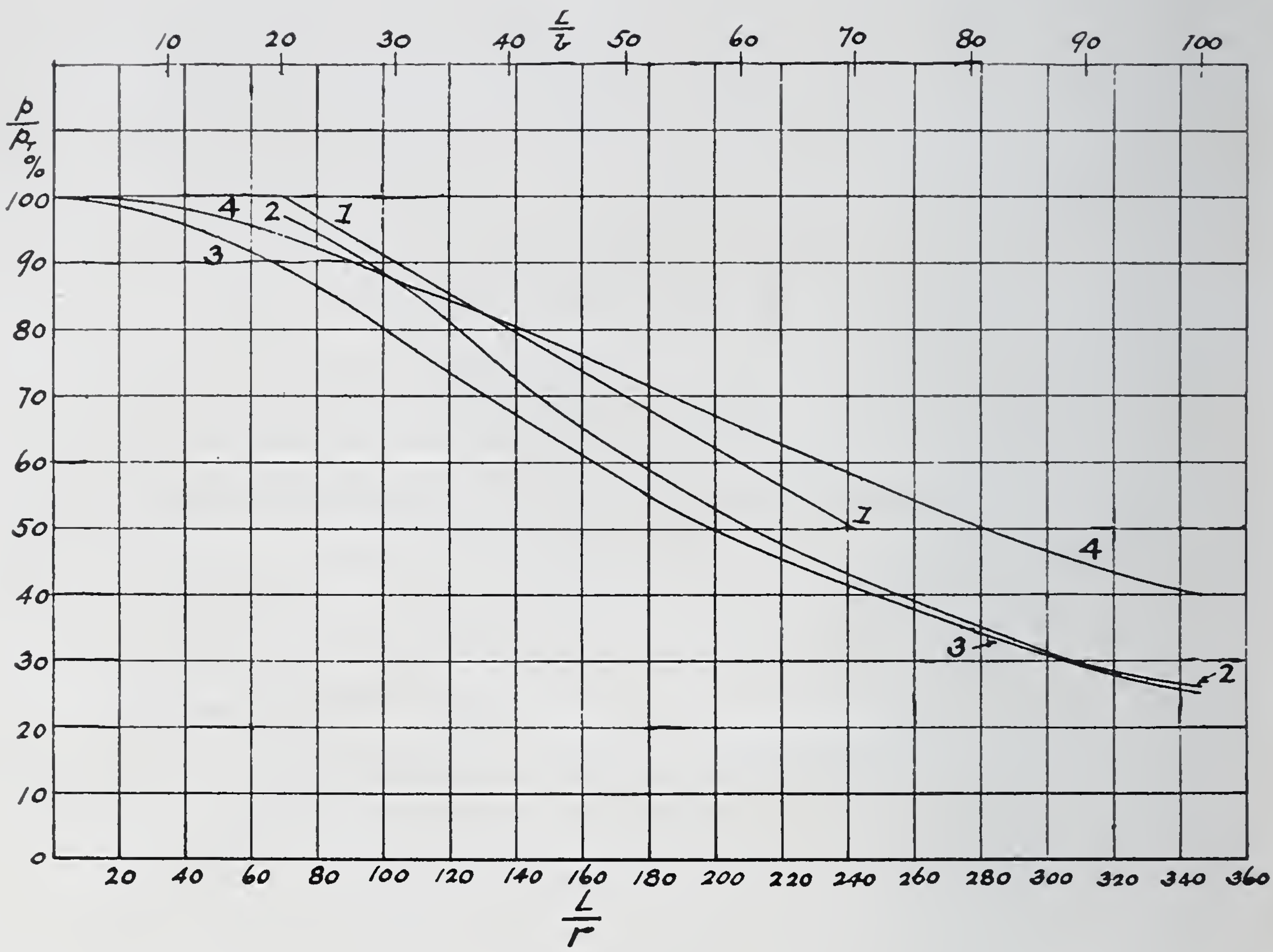

CHART 1.

Curve 1–1, Recommendation of the Pencoyd and Carnegie Hand-books. 2–2, Recommendation Cambria Hand-book. 3–3, Simple beam, uniform load, lateral stiffness due to compression flange only. 4–4, Simple beam, uniform load, lateral stiffness due to both flanges.

The foregoing discussion is intended to apply only to sections similar to the present standard structural shapes. In beams with thin flanges of unusual width lateral failure might occur earlier than would seem to be indicated by the flange width, due to the buckling of the edge of the compression flange about an axis parallel to its top.

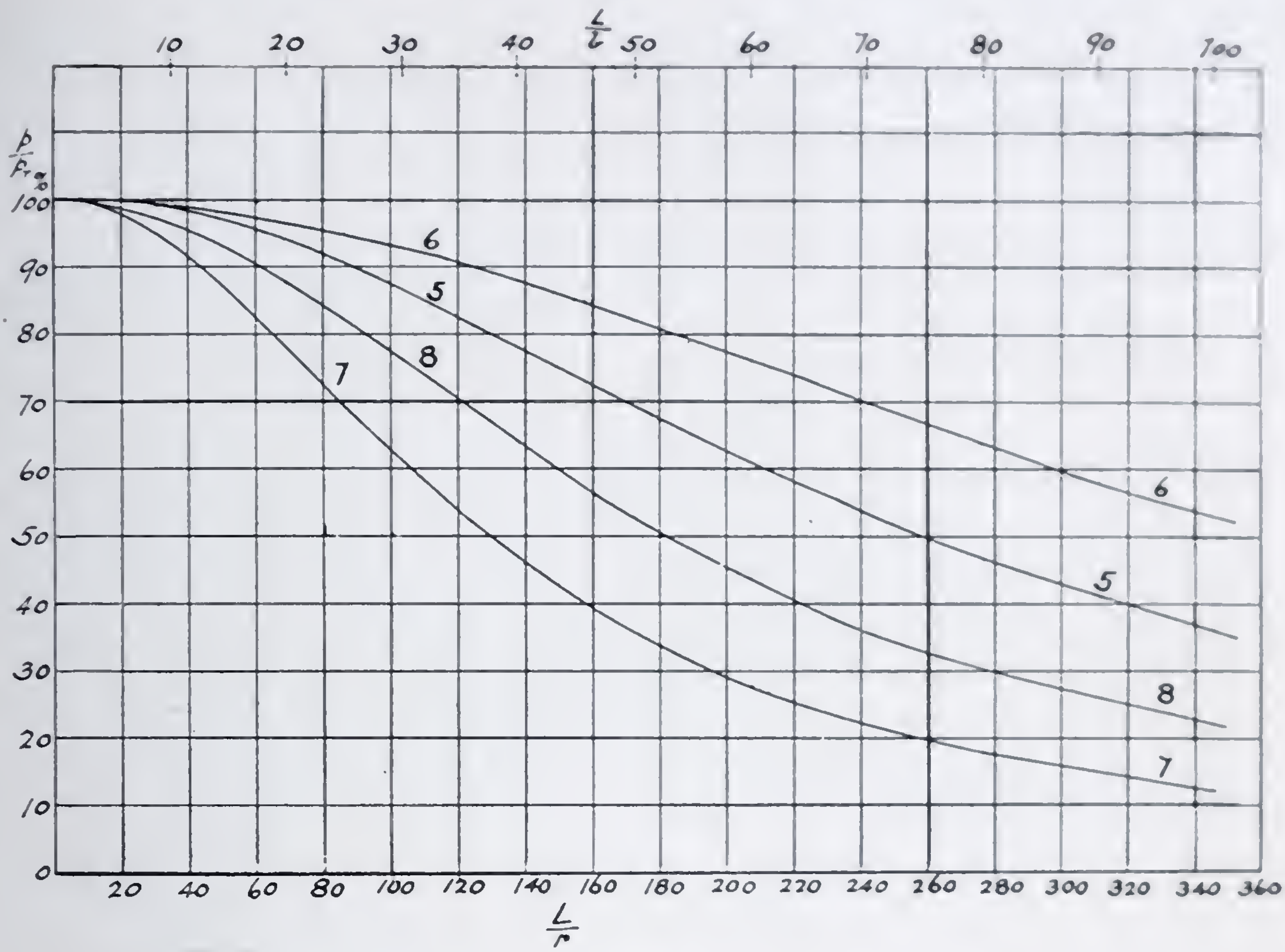

CHART 2.

Curve 5–5, Simple beam, central load, lateral stiffness due to compression flange only. 6–6, Simple beam, central load, lateral stiffness due to both flanges. 7–7, Cantilever beam, load at end, lateral stiffness due to compression flange only. 8–8, Cantilever beam, load at end, lateral stiffness due to both flanges.

DISCUSSION.

MR. JAMES CHRISTIE.—The experiments on beams referred to by Mr. Hess, and conducted under my direction over twenty-five years ago, had for their object an investigation of the strength and stiffness of steel beams as compared to iron beams. Prior to that time little was known definitely regarding the comparative elasticity of the two metals. Some experiments were made on beams of considerable length in proportion to cross-section and without lateral support, the object being to ascertain approximately how the working loads should decrease, as the length of the beam increased. As I remember it, the results of these experiments were unsatisfactory, and although tables were formulated suggesting a scale of reduction for loads on long beams without lateral support, yet these tables had neither a rational nor an experimental basis, but were derived by a general estimate of probabilities. For long beams, when the beam is reasonably straight and its load free from vibration, a large burden appeared to be safely borne. But this was not the case when lateral vibrations were set up. The long beam, heavily loaded, appeared to be in a state of unstable equilibrium. Mr. Hess attempts a solution by supposing the top flange to be acting as an independent strut in compression, and it is gratifying to observe how closely

his results correspond with the tables of the hand-books. But the top flange must receive some uncertain support from the web of the beams, and this fact renders a rational solution of the subject well-nigh impossible.

Mr. Hess.—Mr. Christie's comment that the problem is a difficult if not an indeterminate one is quite right. However, I think that the most that can be expected from the web in a beam of usual proportions is to make the tension and compression flanges both act to resist lateral flexure, hence on the diagram the truth must lie between the two curves. The lower curve shows the effect of the compression flange alone acting, while the upper curve gives the result with both flanges acting to provide lateral strength. In building practice it is rarely necessary to consider the lateral strength of long beams. It might arise in crane runway girders, but would usually be cared for by the specification limiting the span to from twenty to thirty times the flange width. Long beams unsupported laterally are the exception rather than the rule. I believe the necessity either for such lateral support or of a reduced loading is best impressed upon designers and students by such treatment as we have just given. Notwithstanding the several illustrations, which I presume have been cited largely to show how indeterminate the problem is, I do not doubt that we are all agreed as to the necessity for lateral support, or, where this is impossible, either an increase in flange width or a decrease in fiber-stress.

PAPER No. 1069.

TRAINING IN THE ENGINEERING TRADES IN PHILADELPHIA.

PRESIDENT HENRY W. SPANGLER.

Read January 16, 1909.

THE question as to the sort of industrial training the American boy of the present generation is receiving has, for several years past, been of special interest not only to manufacturers and to educators, but to the public generally, as is evidenced by the large amount of attention given to the subject in technical papers and in discussions wherever the question of education may arise, and by the correspondingly large amount of space in the daily papers. That we are a people who are willing to work hard for any sort of an education that will better our individual position is easily to be gathered from the enormous enrolment of the various correspondence schools. That it is the popular belief that specific manual instruction of some sort is especially valuable is indicated by the overflowing manual training schools, trade schools, and technical schools in all parts of the country. The enormous enrolment of persons desiring some particular sort of trade instruction which was obtained in Pittsburg before the construction of the Carnegie Technical Schools clearly shows the sort of instruction desired by the great body of the working people in a great industrial center.

There has been published recently by the Massachusetts State Commission on Industrial Education a partial report of a canvass of the city of Worcester. Taking the figures as condensed by the "American Machinist,"* 3708 families, having children who were last year in the four grades below the high school, were actually interviewed. There were 4625 children in these families—2367 boys and 2258 girls. Of the total number, the parents of 1374 boys and 1185 girls expressed a desire to send their children to a trade school. Less than 10 per cent. of the parents interviewed were indifferent to the establishment of such a school and only two were recorded as opposed to the proposition.

That practically similar results would be obtained by a careful

* December 10, 1908, p. 852.

canvass of any of our large towns having similar industrial conditions will, I think, be conceded.

According to the last census there were in Philadelphia 193,872 males and 65,325 females engaged in a selected list of manufacturing and mechanical pursuits covering eighty-five different lines of work. The question of the training we are trying to give this quarter of a million people in their formative stage is one of great moment, not only to these people themselves but to the industries and to the well-being of our people as a whole.

As an investigation relating to these eighty-five different lines of work would be far beyond the limits of a paper such as this, I propose to confine myself to the preparation of young men only, for taking up their life work in what has been called the engineering trades in this city.

It may be of interest first to attempt to clarify our ideas on the subject of industrial work as handled in the various manual training, trade, and technical schools; to attempt to differentiate between them and to point out what should be the aim of each. To the casual visitor, and to many engineers, the boys are all working at a lathe, or making patterns or drawing, and it is difficult to understand that a year's work in any one of these schools is not exactly the same as a year's work in any other, or even why a year's work in a shop is not much better than any one or all these together. That there is a marked distinction between the aims of the different types of training goes without saying. That the material to be worked upon reaches the various schools in different stages of development is well known. To enter the manual training schools in Philadelphia a boy must have completed the grammar school work, to enter a technical school he must have completed the manual training or high school course, while to enter one of the trade schools a boy in this city is not required to have any specific amount of training, the ranks being filled by students from grammar-school boys to middle-aged men.

The distinction between the aims of these schools has been well stated by Director Kimball, of Cornell. He says: "In manual training the object of the shop work is mostly educational, and is, when properly carried out, only a part of the general scheme of educational development, where the particular shop work employed is not of so much importance as the manner in which the instruction is presented. Its true function is general, and not special, education, and it is rapidly being recognized in secondary schools as an important educa-

tional principle."* Further he says: "The object of shop work in trade schools as practised at present is very different, as here its character is generally quite definitely fixed by the particular trade or trades taught. The instruction, while it may be educational from a pedagogical standpoint, is designed mainly to develop manual skill and to prepare a student for a particular trade or calling in his life work."

Further on he says: "Summing up the foregoing, then, it appears that the purpose of shop work in an engineering college should be to instruct the student in shop methods and processes, and, next to this, to give him such manual development as time will permit."

In a few words, the manual training object should be the training of head and hands simultaneously. Not the training of the head in one line and of the hands in another, as is so often done; but an attempt to develop a moderate amount of hand skill and a corresponding amount of head skill as applied to the work of the hands. As in mathematics a student must solve problems, must be able to apply on paper the principles he has worked out in the text, so in manual training the education is only a weak, one-sided, worthless attempt at trade training if the "why" of each step is not as thoroughly inculcated as the "how."

In a trade school, on the other hand, a boy should be taught hand skill first, last, and all the time; how to do the work better and more quickly, and in addition he should have all the collateral training necessary to a thorough understanding of the work he is doing—but not an hour's work that has no bearing on his trade. A limit should be set as to the minimum general education a boy should have, which minimum would often have to be lowered in individual cases. The more quickly our good people realize that a man is an educated man only when he can *do*, and that a smattering of many things is of infinitely less value to a man and makes him a worse citizen than if he had an exact knowledge of any one thing, the sooner will such training be of distinct value to the community.

It is not, however, the intention to talk of industrial training in general, but rather of the training of the boys of Philadelphia.

Attention is first directed to what some Philadelphia boys are doing. The diagram, Fig. 1, represents the distribution of such Philadelphia boys as attend the public schools in all the various grades. The hori-

* Amer. Mach., April 19, 1906, p. 409.

zontal distances are ages, there being one division to the year. The vertical divisions are thousands of boys—2000 to the division. The irregular lines show the number of boys in the public schools of each of the various ages. The full line indicates the line for January 1, 1908, the long and short dash line that for 1907, and the short dashes show the condition in 1906 on January 1st.

The limits of so-called compulsory education in this State are indicated on the figure. What a farce it is!

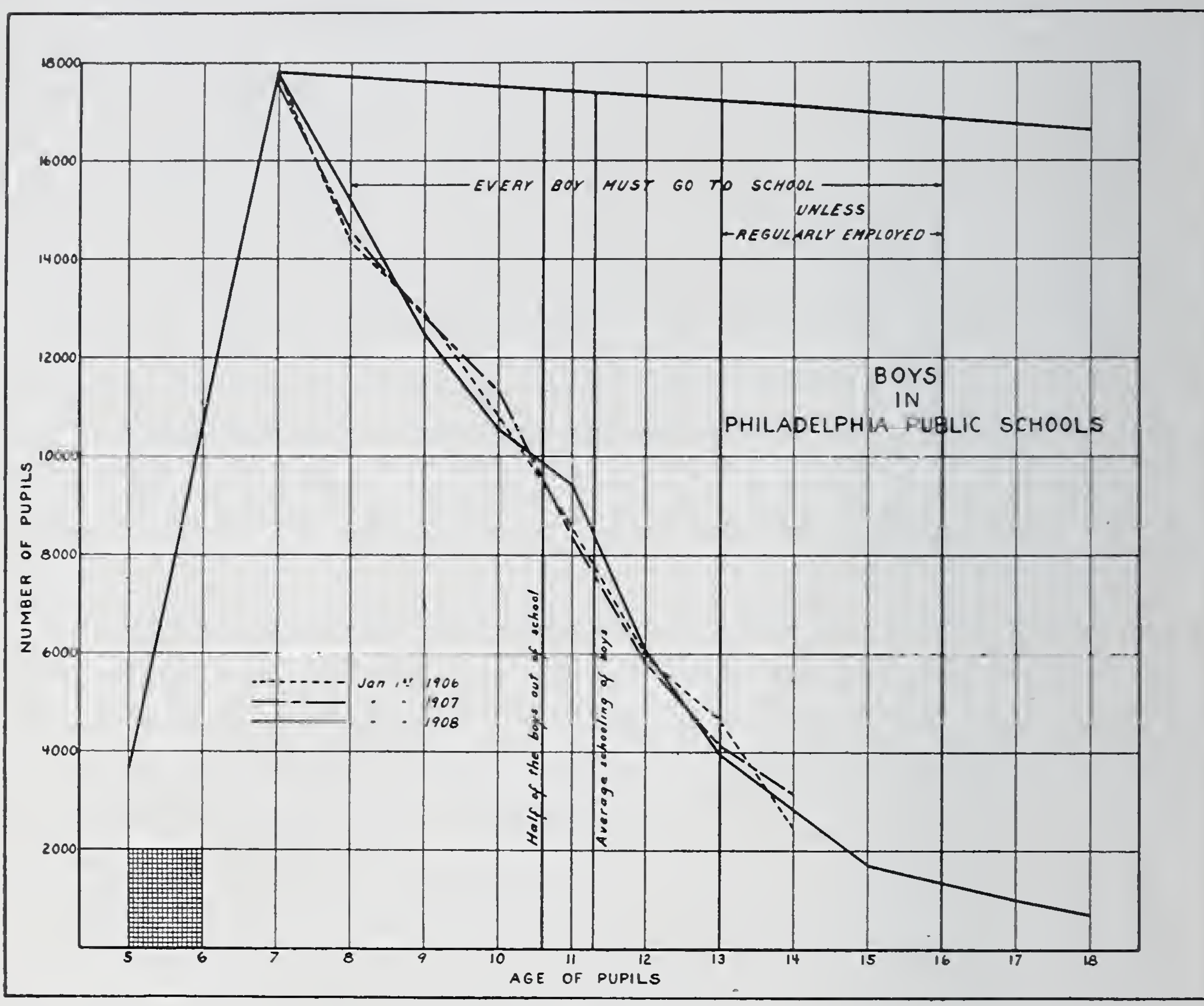

Fig. 1.

The boys begin to drop out of school from the beginning; what becomes of them all? A few—not many—die. The nearly straight line at the top of the diagram shows the probable number living at any one age. The average curve of attendance does not differ much from that of any one year. Half the living boys have left school at 10.6 years of age. A few days ago a circular was sent to me announcing a discussion on the general subject, "Do one-quarter of our children fail to receive an education?" The answer seems to be, more than half do not receive an education that is at all fitted to their needs. The

diagram shows that the average schooling received by all the boys in the public schools is completed at 11.3 years, or in a little over four years.

The Commission on Industrial Education of New Jersey, in its report to the Governor, made only a week ago, says as relating to that State: "The records of the Commission show that approximately five-sixths of those who enter the lower grades of the elementary school drop out before the completion of the eighth grade. They drop out chiefly because of the necessity of earning a livelihood."

Of the boys born in 1894, 3000 are in school; 14,000 are out of school—of which the major portion are probably working. One thousand five hundred left school in 1908, 1800 in 1907, and 2000 when they were eleven years old. What has been done for the portion that would naturally be drawn upon to fill the ranks in the industries that we are particularly interested in? How many are there of these that should be taken care of?

This discussion is limited to what might be called the engineering trades, which include machinists, iron- and steel-workers, brass-workers, foundry-men, and pattern-makers. The twelfth census shows* that in the total number of selected groups, including those above referred to, there were in Philadelphia 421,270 males and 147,653 females, or a total of 568,923 workers.

15,170 males were between ten and fifteen years of age. There were 634,485 males in Philadelphia at the time of making the census, practically two-thirds of whom were in the selected lists above.

Referring now to the trades under consideration, the census gives the following distribution:

TABLE No. 1.

	Totals.	White.			Colored.
		Native Parents.	Foreign Parents.	Foreigners.	
Brass-workers	1,441	576	491	371	3
Iron- and steel-workers	9,874	3,129	3,137	3,432	176
Machinists	15,050	5,989	4,672	4,341	48
Model- and pattern-workers	817	424	246	147	..
Steam boilermakers	1,631	486	549	596	..
	28,813	10,604	9,095	8,887	227

As at the age of fourteen there have been passed out from the public schools each year about 14,000 boys, about two-thirds of them, or

* Occupations, p. 672.

9300, should each year be taken into the selected groups of trades above referred to.

In manufacturing and mechanical pursuits there should be taken about $\frac{193}{421}$ of these, or 4265, and in the five lines of work selected as the engineering trades about $\frac{28}{421}$ of them, or 619. As, in general, the term of apprenticeship is four years, one would expect to find in Philadelphia at that time about 2476 apprentices, or, say, one apprentice to every 11.5 workers, or one in every 10.5 journeymen.

This gives a basis for determining whether or not the engineering trades are properly preparing for the future, or whether they are living for the present and allowing the future to take care of itself.

There has lately been prepared a report by a committee of the American Railway Master Mechanics' Association and presented at the Atlantic City meeting, June, 1908,* giving the results of investigations as to the condition of affairs relating to apprentices in the railroad shops of the country. Taking from this the data relating to those of the above referred to trades, table No. 2 is obtained:

TABLE No. 2.

Trade.	Number of Journeymen.	Ratio Journeymen to One Apprentice.	Apprentices.
Machinists	23,100	4.8	4814
Pattern-makers	211	3.3	64
Molders	672	8.2	82
Boilermakers	6,474	6.8	952
Total	30,457	5.1	5912

It is exceedingly interesting to note that the Committee found it was the practice, in attempting to "develop from the ranks in the shortest possible time carefully selected young men for the purpose of supplying leading workmen for future needs," to take one apprentice from practically each 5.1 journeymen; while from the figures deduced above to take care of the boys leaving the public schools, at least one apprentice should be taken in the industrial works for each 10.5, or less, workmen.

How does Philadelphia practice compare with the absolutely necessary 10.5, or with what has been found desirable in the railroad shops, 5.1?

To arrive at figures which would be of some value, blanks were prepared and sent to 72 leading and smaller industrial establishments

* The Railway and Engineering Review, July 4, 1908, p. 553.

located in Philadelphia, and having presumably workers, and possibly apprentices, in their employ, of the types referred to above.

A copy of the sheet of inquiries is given in the appendix hereto and need not be gone into in detail here. The results will appear as we proceed.

The queries were so framed that the number of all-around mechanics, the number of what might be called specialists, or one or two tool men could be separated, and that the number of apprentices and of boys not apprentices might be determined.

Practically all the larger establishments written to returned full answers to the questions, in many cases writing explanatory letters which were of much service in collating the results. In all, 44 concerns out of the 72 replied. The following are the results as to numbers:

TABLE No. 3.

Number of all-around machinists	5533	
Number of single-tool machinists	4111	
Total machinists		9644
Number of apprentice machinists	590	
Number of boys not apprentices	799	
Ratio of apprentices to machinists	1 to	16.4
Ratio of boys and apprentices to machinists	1 to	7.1
Number of all-around foundrymen	906	
Number of foundry specialists	199	
Total foundrymen		1105
Number of apprentices in foundry	74	
Number of boys not apprentices	85	
Ratio of apprentices to foundrymen	1 to	14.9
Ratio of boys and apprentices to foundrymen	1 to	7
Number of pattern-makers	353	
Number of apprentices	64	
Ratio of apprentices to pattern-makers	1 to	5.5
Number of all-around boilermakers	1958	
Number of apprentices in boiler work	11	
Number of boys not apprentices	89	
Ratio of apprentices to boilermakers	1 to	179
Ratio of boys and apprentices to boilermakers	1 to	19.6
Total number mechanics	13,060	
Total number apprentices	739	
Total number boys	1712	
Ratio of apprentices to mechanics	1 to	17.7
Ratio of boys and apprentices to mechanics	1 to	7.6

It may be of interest to bring together these results and those previously referred to from the railroad shop. It is, of course, to be understood that this is the rudest sort of a comparison, but it will emphasize the contrast.

TABLE No. 4.

	Number of Mechanics to One Apprentice in:	
	77 Railway Shops.	44 Philadelphia Shops.
Machinists	4.8	16.4
Foundrymen	8.2	14.9
Pattern-makers	3.3	5.5
Boilermakers	6.8	179.0
All	5.1	17.7

These returns cover $\frac{13}{29}$ of all the mechanics in the trade in 1900, and probably are well inside of one-third of all such mechanics in Philadelphia to-day. Each query sheet was headed, "The following inquiries refer to ordinarily prosperous times and not necessarily to present conditions." There is no uniformity or regularity in the distribution of apprentices. Thus in the machinists' trade there are such returns as 36 machinists, 0 apprentices; 95–0; 486–60; 71–0; 622–63; 160–13; etc. In the foundry departments the figures run 425–31; 304–14; 26–0; 54–2; 90–4. In the pattern shop the figures run 160–17; 65–16; 20–2; 8–3; 4–0; 10–5. In the boiler ships there are practically none.

If the same average holds for the entire engineering trades, there should be for 30,000 workmen at least 3000 apprentices in Philadelphia to absorb its share of boys; instead of that there are probably not over 1700 in all these trades. To supply its share of the future workmen, and if the railway shops can be used as one indication, there should be 5500 apprentices in the shops in this city. If all the boys now in the trades were apprentices, Philadelphia would still not be doing its share.

Mr. John E. Sweet pointed out ten years ago why this condition of affairs exists,* and it all can be summed up in the sentence, "Employers do not want apprentices because it does not pay." He also clearly pointed out that a modern machine shop, equipped with large and complicated special tools, which must be operated at their maximum efficiency and with the maximum output to justify their installation, was the most expensive school in which to teach a boy a trade.

For there is usually a definite argeement "to teach and instruct or cause to be taught and instructed," as it is stated in a number of in-

* American Machinist, Sept. 7, 1899, p. 838.

dentures of apprenticeships; or, as another states it, that he "will receive from competent instructors all the instructions, opportunities, and assistance . . . needful for him to acquire the art and mystery of," etc.

It seems, therefore, that, as has been generally recognized, the apprenticeship system as now practised in the Philadelphia engineering trades is inadequate to take care of its own quota of the public-school boys who should gravitate into these lines of work, and that it has long been so is well understood. That these public-school boys are far from being the total number of boys who should go into these trades is also well known.

The New Jersey Commission has found the same conditions to exist, and finds that "the apprenticeship system has been virtually abandoned as a means of instructing the young in the various trades; that there is a lack of skilled and efficient workmen, which will be largely increased, unless a better means of vocational training is found, and that the schools have not been able to offer vocational training."

The census report shows that the absorption has not been enough to supply the demand in the past. The division of these mechanics into classes as quoted above, while not showing the place of birth, does show that about one-third of all these mechanics are of foreign birth.

The invasion by foreigners in the trades is suggested very strongly by the sign (see Fig. 2) which was photographed at the entrance of one of the large industrial establishments in Philadelphia.

Most of us are convinced that the present condition will continue, and may even become worse, and it is perhaps as well that it should.

A more vicious waste of time than the old apprenticeship system never existed, and the idea that it took four years or five or six to learn any trade was fostered by selfish tradition which extends even into the industries of to-day, many of which speak of the "mystery" of the machinist's trade or of the molder's trade.

A curious commentary on the old system, which if extended might apply to what is known as the later and better methods of teaching trade, is this: In certain large industrial works apprentices are divided into classes. One boy comes from the grammar school, has had no manual training at all, and must work four years as an apprentice. Another comes from a manual training school, where he has been three years. He is perhaps two or three years older than the first when he leaves school and is consequently able to more quickly grasp

the ideas that may reach him, but he is probably of the same age as the boy of the first class when he begins his trade. He has been working in the shops and drawing-room about six hundred and forty hours. This work and his quicker grasp due to this work relieve him of one year of his apprenticeship, and this eighty days is nearly the equivalent of a whole year's apprenticeship.

Another class comes from the technical school, where in most cases a certain amount of manual work is done. This amounts to perhaps

FIG. 2.

three hundred and sixty hours in all—not over forty-five eight-hour days—and this, with greater ability to absorb, is the equivalent of two years' apprenticeship. But it will be said that he is able to read drawings, and is therefore farther along than either of the other classes. Thirty eight-hour days cover the drawing field. Seventy-five working days in a school not intended for trade teaching, as against six hundred days in a shop! These may not be equivalents in any sense, but if seventy-five days' teaching in a school not founded for turning out tradesmen is even the equivalent of one hundred and fifty days in a

shop, the training of men in industrial establishments has not kept pace with that increase in efficiency which is the marked characteristic of American industries.

But to look at the shop end a little closer, there is no better criterion to apply than the second of the principles quoted from the report, relating to railroad shops, already referred to, which says: "To assume the success of the apprenticeship system, the following principles seem to be vital, whether the organization is large or small." . . . .

"Second—A competent person must be given the responsibility of the apprenticeship scheme. He must be given adequate authority, and he must have sufficient attention from the head of the department. He should conduct thorough shop training of the apprentices, and, in close connection therewith, should develop a scheme of mental training, having necessary assistance in both. The mental training should be compulsory and conducted during working hours, at the expense of the company."

The queries mentioned before enable us to apply this test to practically all the shops referred to, and the answer to the following questions may also be of help:

1. Who are in charge of the apprentices?
2. Are the apprentices required to attend school or to do any studying?
3. Is such work done in the firm's time or outside?
4. Do you have a satisfactory way of controlling what an apprentice is supposed to study or does he select for himself?

The answers to the first question run from "no one" through "gang foreman," "foreman," "superintendent," to a particular man whose special business is to look after the apprentice and his work. Of the 739 apprentices accounted for above, 522 are directly in charge of some one man, the others being in charge of "no one" or a man filling some particular position. That is, for possibly 70 per cent. of the apprentices in Philadelphia the first requirement is met. In over 50 per cent. it is excellently met.

As to the second question, two concerns only require their apprentices to do certain school work. One other concern "encourages" their apprentices, and the writer says: "In some trades where the work is light . . . a growing boy . . . can work ten hours a day and go to school . . . in the evening without ill effects. In other trades when the work is laborious, this is impossible except in

TABLE No. 5. INDEX

						PAY				OVERTIME	
TERM OF APPRENTICESHIP	AGE AT START	PRELIMINARY EDUCATION REQUIRED	SCHOOLING REQUIRED	SHOP CHANGES	PROMISE TO TEACH	1ST PERIOD	2ND. PERIOD	3RD PERIOD	4TH PERIOD	PAY	TIME
UNTIL 21	17	GRAMMAR SCHOOL	1ST YR ELEM ALG. GEOM 2D & 3D YRS MECH. DR.	EVERY 3 MO.	YES	10 HRS. 310 DAYS 5¢	10 HRS 310 DAYS 7¢	10 HRS 310 DAYS 9¢	REST 11¢	SAME RATE	COUNS ON TIME
UNTIL 21	17	ADVANCED GRAMMAR OR HIGH SCH	1ST & 2D MECH DRAW	EVERY 3 MO	YES	7¢	9¢	——	REST 11¢	SAME RATE	COUNTS ON TIME
2 YRS	OVER 21	TECHNICAL GRAD	——	——	WILL KEEP AT WORK	13¢ 16¢	18¢ 20¢	——	——	——	——
——	——	——	——	AS CO SEES FIT	OPPORTUNITY TO LEARN	56¼ HRS $3.00 WK	56¼ HRS $4 00	56¼ HRS $5.00	$6 00	——	——
UNTIL 21	17	——	——	——	——	FIXED BY YEAR INDIVIDUALLY				DOUBLE PAY	COUNTS SINGLE
4 YRS	17	——	——	——	YES	56% JOURN wages $4.00	$4 50	68% JOURN wages $5 00	$5 50	——	——
4 YRS	——	——	——	——	YES	2948 4 37¢	2948 5 23¢	2948 6 11¢	2948 6.98¢	——	——
4 YRS	——	——	SCHOOL AS DIRECTED	——	YES	2880 8¢	2880 9¢	2880 11¢	2880 13¢	SAME RATE	COUNTS ON TIME
2 YRS	——	——	——	——	YES	2880 15¢	2880 17½¢	——	——	SAME RATE	COUNTS ON TIME
5 YRS	16	——	——	——	——	——	——	——	——	——	——
FIXED BY COMP.	——	——	——	——	——	60 HRS = 1 WK.			——	SAME RATE	——
UNTIL 21	——	——	——	——	YES	3100 HRS = 1 PERIOD			——	SAME RATE	——
UNTIL 21	——	READING, WRITING & ARITHMETIC	——	——	——	2925 4½¢	2925 6¢	2925 6¾¢	REST 7½¢	——	——

the cases of boys of exceptional physique and character. Personally, I have grave doubts as to whether any benefit is derived from forced study of this kind." Another says "advised, but they don't do it." Practically all the smaller concerns answer "no."

Over 50 per cent. of all these apprentices are required to do some school work; hardly 10 per cent. are required to do it under conditions that are fair.

The answer to the third question is rather included in the second, and the replies show that only one concern provides for the doing of this work in the firm's time, and one other provides for doing it at the firm's expense in the apprentice's time. That is, the conditions under which 90 per cent. of the apprentices can get such education as may be of service to them, and which in most cases is necessary to initiate them into the "mystery" of the trade, are only to be condemned. More and better work would be done each day if proper provision were made in the firm's time and at the firm's expense for systematic training day by day or week by week in the comparatively few things of real value to a competent mechanic that can be better obtained out of, rather than in, a shop; and I have never heard that the concern doing this work in this way was the financial loser thereby, and experience

TURE CONDITIONS.

LAY-OFF		SICKNESS		ACCIDENT							
PAY	TIME	PAY	TIME	PAY	TIME	LOST TIME	BONUS	BONUS FOR PART TIME IF MUTUALLY CANCEL.	EARNEST MONEY	LABOR ORGANIZATION	PROBATION TIME
NO PAY	REDUCE TIME	—	—	—	—	—	\$125	PRO RATA	—	—	—
NO PAY	REDUCE TIME	—	—	—	—	—	\$100	PRO RATA	—	—	—
NO PAY	MAKE UP	—	—	—	—	MUST BE MADE UP	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—
NO PAY	COUNTED	—	MAKE UP	30 DAYS ON PAY	COUNTED	MAKE UP	\$100	PRO RATA	—	—	6 MO
NO PAY	—	NO REDUCTION	—	—	—	—	10% WAGES	—	—	MUST NOT JOIN	1 MO
NO PAY	AT DISCRETION OF CO.	—	—	—	—	MAKE UP	\$100	—	\$50 RETURNED	—	3 MO
NO PAY	REDUCE TIME	—	—	—	30 DAYS COUNTED	MAKE UP	1¢ PER HR IF STILL EMPLOYED AFTER 6 MO	—	—	—	720 HRS
NO PAY	REDUCE TIME	—	—	—	30 DAYS COUNTED	MAKE UP	—	—	—	—	—
NO PAY	—	NO PAY	COUNTED IF SEVERELY SICK	—	—	MAKE UP	FIXED BY CO	—	—	—	—
NO PAY	—	—	—	—	—	—	FIXED BY CO	—	—	NOT TO JOIN	—
NO PAY	—	—	—	—	—	—	2¢ PER HR	—	—	—	NOT OVER [illegible] 3 6¢ PER HR
—	—	½ PAY FOR 3 MO	COUNTED	—	—	—	\$1 00 PER MO	—	—	—	—

in other cities has shown that this method of instruction results in decided financial gain.

As to the fourth question, one concern says, "the company controls"; another says, "work is prescribed"; all others say "no." The first answer is the only satisfactory one.

To summarize this second requirement, one-half the apprentices are under satisfactory control, one-half are required to do studying, one-tenth are given proper facilities, and as many as one-half may have their work properly supervised. Not a very good showing, is it?

The table on pages 124 and 125 is a résumé of the conditions in the indentures which are used by a number of concerns using these formal documents. The blanks mean that no mention is made of the subject referred to. The headings clearly indicate the information given in the table.

What is being done for the boys who are not getting the training which is necessary for the complete training in the "mystery" of their trades? and what for two-thirds of all the boys who should be taken care of, but who have not the opportunity to work as apprentices at one of our industrial establishments? There are such places as the Franklin Institute Drawing School, the Spring Garden Institute,

the Mechanics Arts courses at the Drexel Institute in one class, the Philadelphia Trade Schools in a second class, and the Williamson Trade School in a third class.

The first class does not pretend to turn out skilled mechanics, except in drawing. These are the schools in which many of our mechanics have obtained all the instruction they have ever received in drawing, and excellent work has been done by all of them. They are fostered and maintained by individual endeavor, the teaching is done by men who in many cases are already tired by a long day's labor, yet nothing but praise can be given for the work done and the results produced. These schools, however, do not begin to do the work which should be done; because, first, their facilities are inadequate; secondly, they reach few of the boys who are otherwise being neglected; third, with the limited facilities and small teaching staff, no system of instruction can be instituted and carried out which will enable a student to do in the quickest and best way the work which he undertakes. A carefully thought out system of instruction, with each piece of work designed to teach some one thing only, and each piece of work so carefully done, supervised, and examined that the particular point intended to be covered becomes part of the student's equipment, seems the only rational method of procedure. There seems to be as little sense in giving a beginner an intricate drawing for the purpose of teaching him the use of his tools as there is in the continual repetition of elementary exercises, at the opposite extreme, with, in both cases, inadequate personal instruction, and without that careful checking and repetition necessary to obtain workmanlike skill in each operation as a boy develops.

However the operation of these schools may be viewed, they can only be classed as valuable aids to those already in the trades, and, except in few instances, cannot be spoken of as trade schools. In other than drawing subjects they are distinctly manual training schools, and as such are outside the scope of this paper. There is one particularly excellent feature, however, about them all, and that is, that history and logic, higher mathematics, and literature have no part in their training of mechanics, as the object of the training is simply to make better mechanics. The author wishes to emphasize the belief that a man who can *do* things, and knows he can do them, is the peer of the product of any other sort of training, and that the republic has no better citizen than the expert mechanic, and no saner, happier, safer class exists than that of the self-respecting expert who works with his hands.

The history of education in the public schools of Philadelphia is full of references to the desirability of trade training. In the report of 1854 a course in civil engineering was founded in the high school sixteen years after the high school was itself founded and only twenty years after the present system of free public schools was instituted. Fifteen years later, in 1869, the Artisan's Night School was founded. Beginning with 1876, the subject of technical education in the public schools began to be agitated; a committee was appointed four years later, and in 1883 it was decided to approach Councils on the subject, resulting in the first appropriation in 1884 and the establishment of the Central Manual Training School. The following year the School of Industrial Art was reorganized, in 1890 the Northeast Manual was established, and in 1891 the Forten School. Three years ago the Philadelphia Trades School No. 1 was established at Twelfth and Locust and a second school is now conducted in the old Northeast Manual Training Building.

It has long been recognized that the field to be filled by the trade school is something entirely different from that filled by the manual training school. Only the first of these is to be dealt with here. The first impression one gets in visiting a trade school is that its friends are few and widely separated. The building in which Trade School No. 1 is located is a disgrace to the city, and the second is in a building which is even poorly adapted for entirely different work. The equipment is a farce. Bricklaying and plastering are taught in a basement hardly seven feet in the clear, pattern-making in a plant without a single pattern-maker's lathe, plumbing in a shop with no material or appliances except those necessary to make a wiped joint, drawing taught in a room packed so full that it reminds one of a sweat-shop—and this is the second greatest industrial city in the country!

What can be said of the students? The night classes impress one most forcibly—a keen, alert crowd of young men and boys, putting in each minute with an earnestness to be found in few schools of any other type, trying to make each minute count. The work, fortunately, is trade work with no frills. It is rather a pathetic group of students—a single-tool machinist learning the plastering trade; a grocer learning bricklaying; a printer studying sign painting; a boy about sixteen just beginning his apprenticeship as a machinist and spending three evenings a week at mechanical drawing, and he says it makes a pretty hard day; some of them come back for the second year, but more are

dropping out. One cannot fail to be impressed with the wonderful field ready to be worked.

What can be said of the teachers? They are mostly mechanics, and good ones. They are doing the best they know how, but there is all the difference in the world between knowing how to do a thing, and knowing how to teach others to do it.

A few conclusions from the author's experience in a slightly different line may illustrate this. Prior to 1890 the mechanical students of the University of Pennsylvania went to another institution in the city for their shop work. About that time it was decided to establish shops at the University. A shop on a small scale, with a moderate amount of apparatus, was installed. Instructors were engaged and the work started. Little difficulty was found in getting good mechanics to take charge of the work and to plan out the details. Before a half year was finished there seemed to be something wrong; the work was listlessly done, seemed to be haphazard in its order and sequence, and we soon became convinced that the right thing was not being done. Instructors were changed and a new start was made. It was soon apparent that too much was attempted, and it was decided that all efforts should be given to developing one line of work. Exercises were tried and dropped; no exercise was kept that did not open a new door to the student, and the end of that year saw some advance in what seemed to be the right direction. It was quite eight years before the teaching force had been educated to the work it was trying to do in that line alone, and it was four years longer before the other line of work was on such a basis that not a minute of the student's time was wasted, that nothing was done which had not been carefully thought out and planned to give the best return for the time spent by the student; and while the work in these two lines now is changing from year to year, it is as far from the usual work done in shops of this class as the work of the pattern-maker is from that of the "hatchet and saw" man. We are satisfied now if a new man—an expert in his line—becomes only a tolerable teacher in that same line in three or four years.

The fact is that most mechanics—and this applies to foremen quite as much as to journeymen—know many details, but have little general grasp of their trades. To teach successfully requires both to a very great extent.

The New Jersey Commission says that one great difficulty in the organization of industrial schools of elementary grades is "the lack of

instructors qualified to undertake the very practical teaching that is required."

Practically all the teachers who are doing the work in the trades schools—and with few exceptions—are men absolutely untrained in the art of teaching their trades. The result which is sure to follow is that teaching begins nowhere and ends nowhere.

The work that is done in many lines is very practical, and admirably done, considering the facilities and the material to be worked upon; but when real trade instruction is established the present work will be looked upon much as an old vice hand looks at the key finished by a first year's apprentice.

What has been said above applies to the night classes only. That done by the day clasess is in an entirely different category. In the author's opinion, the best that can be said of them is that they should be abandoned forthwith. Boys that can go to the day trade schools as now established should be forced to go to the regular day public schools and be kept there as long as the law will permit.

Again quoting from the New Jersey reprint: "The masses of these individuals cannot be reached by any sort of a day vocational school. They must get their training in the evening, and the number of such is approximately 95 per cent. of the total of individuals who can be reached by any type of industrial school which trains directly for a vocation."

It may be interesting to know what is taught at these trade schools and how the time is divided. There are classes in bricklaying, carpentry, plastering, plumbing, printing, electrical construction, architectural drawing, mechanical drawing, sheet metal working, patternmaking, pipefitting, house and sign painting, and graining. The work is laid out to cover three years and covers thirty-five hours per week during each school year, making possibly 3150 actual working hours in the three years that are given in the course. About 10 per cent. of the time is given to the study of English, and 12 per cent. of the time is given to a series of subjects called "Study of Industries," "Economic History," "Business Organization and Methods," which are of as much value to the prospective mechanic as Sanskrit. Mathematics and applied science are given 15 per cent.—about 450 actual hours; to drawing is given 19 per cent. of the time, and to shopwork the balance, or 44 per cent.; and this is called trade instruction.

A division of the work giving 5 per cent. to English, 10 per cent. to

mathematics, 10 per cent. to drawing, and 75 per cent. to the trade will make a better mechanic and in much less time.

The belief that it requires three years under competent direction to teach a boy a trade is not well founded. A graduate of several years' standing of one of the real trade schools, who is an expert workingman, and who earned last year the highest rate of wages paid in his trade, said in all seriousness that he was an expert workman, and that, beyond a few trade customs, he had learned nothing of his trade since leaving the trade school; and, farther, that the total trade instruction he received in the trade school did not exceed seventy-five working days of eight hours each. The "art and mystery" of this particular trade does not seem a particularly difficult thing to learn. Practically the same thing can be said of any of the engineering trades, although some will require much more repetition work before a beginner becomes an expert workman.

The same fact is set forth by many men competent to speak on the subject. Mr. N. W. Alexander* says: "Fairly good lathe, shaper, planer and boring mill hands can be turned out after six or nine months' evening instruction, and universal milling machine operators in about a year's time."

Mr. H. K. Hathaway† says: "Under the Taylor system it has been found possible to take an absolutely green man who has never worked in a machine shop and make an efficient operator of him on a drill press or turret lathe in from six to eight weeks."

The third and last class referred to above is represented by the Williamson Trade School—an ideal plant for the education of a few superior workmen. Each student is taught one of five trades: viz., carpentering, bricklaying, machine trade, pattern-making, or stationary engineering. Instruction in mechanical and free-hand drawing is given to suit each particular trade. In addition, the student is taught the ordinary English branches, mathematics through trigonometry, and a few of the subjects which have no place in a trade school of any kind—such as physical and political geography, history, physical science, English literature, physiology and hygiene, civil government, elementary vocal music; and, again, some of the subjects especially pertaining to certain of the trades, such as the theory of the steam-engine, strength of materials and building construction. The student is taken at sixteen to eighteen years of age and leaves

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* A. S. M. E., Dec., 1906, p. 452.

† A. S. M. E., Dec., 1906, p. 467.

from nineteen to twenty-one years. The age of the student is more nearly the same as in the technical schools or at the age when the usual apprentice begins, but not at the age when the great mass of boys need the training. On Fig. 1 they would appear about at the second year in the high or manual training school. A short consideration of its curriculum shows that it is not journeymen the school is trying to train, but foremen, assistant superintendents, etc. One of the concerns replying to the above inquiries says that "these boys make good machinists, good foremen, and many of them good clerks." In fourteen years there have been 294 graduates as machinists and pattern-makers.

Whether the future is to see the all-around mechanic disappear or not is perhaps an open question. The committee of the American Master Mechanics' Association seems to think not. On the other hand, the increasing number of single-tool men requiring much less training, and, under some such system as the Taylor system of shop arrangement, increasing in number, seems to show that the number of such all-around mechanics will become less and less necessary. The same concern referred to above in relation to the Williamson School says: "The Taylor system of shop management enables us to train a man to operate one machine, and operate it effectually, and in a much shorter time than we can an all-around man. It enables us to take a man who ordinarily never rises above the unskilled class and make a machine hand of him. It enables the operator to earn higher wages than he would otherwise receive, and at the same time give us a greatly enlarged output with low labor cost."

One wonders whether it will finally adjust itself to a few all-around workmen for tool-room work and that class of labor, a few all-around mechanics ultimately to become sub-foremen and foremen, and the great mass of the men who take the place of the present mechanics as "operators" only. The author does not believe that such will be the ultimate outcome, during the present generation, at least. The sociological changes this means are so great, and so foreign to our traditions, that it is doubtful whether it will ever come about.

In the meanwhile what can we do with these boys? The industries will not take them under present conditions, and either individuals or the State must. Why not individuals? Why should not some wealthy men become interested in this matter and establish schools to take care of these boys? For two reasons: first, because many of them must become self-supporting as soon as possible, not only supporting them-

selves, but must aid in the family support; and, secondly, except in rare cases, any such establishment by an individual results, either during his lifetime or during the following generation, in an attempt to do the so-called higher educational work, which defeats the aim of the foundation.

Why should not the State undertake it? It should, if it were feasible; but again the question of the necessity of earning a living comes in to prevent those most needing the education from availing themselves of it. There would, however, be enough boys available for such education to fill to overflowing any such schools that the State might establish. Any sort of a school of this type, whether good or bad, would be filled. Who is to know whether such a school is good or bad—not the professional educators, not the college professors, but the men in the industries themselves.

Mr. W. B. Russell, in a paper on "Industrial Education," relating principally to the system of shop apprenticeship on the New York Central Railroad,* says: "Educational ideas have been reversed. Much that is dear to the mathematician and the physicist has been discarded. . . . The problems are worked in the language of the shops. . . . The whole scheme of education is simple and more elementary than usual, although it is made to include many principles of mechanics. In fact, the course of study fits the conditions, and the conditions are not those imagined by most educators."

Mr. J. E. Sweet, who is usually an optimist, says:† "I can see no way by which a *school of trades* can be established except by the gift of some wealthy man, and even then, when the man appears, the school is so likely to fall into the hands of school men that it is more likely to turn out a technical school than a place for a boy to learn a trade."

No man can evolve an efficient trade school from his inner consciousness. Only men who are constantly in contact with the desired product, who preferably have come through the ranks themselves, have opinions worth considering; and men of this type who have had to do with such education—and there are a number in the city of Philadelphia—should have a large hand in determining the curriculum, policy, and management of such schools.

There are trades in which all that can be taught in a school of any kind can be completed in a single year; there are some that probably would take two years, and very, very few that would take more, pro-

* A. S. M. E., 1907, p. 1124.

† Am. Mach., Oct. 22, 1903, p. 1493.

vided that "trades" are taught and all things necessary thereto—and nothing else.

Why is it not done? Simply because the reasons for doing it have not yet been presented with sufficient force. The steps that should be taken include the careful collection of statistics, and an analysis of the existing conditions from the standpoint of both the boy and the manufacturer, together with the publication and public discussion of all such data.

This should be followed by an attempt to do the work in one or two related trades, under a competent board of control selected from these trades. No attempt should be made to cover a great range of industries, nor should widely different trades be put under a common control. Only a moderate outlay would be required to instal a plant for such work that would be beyond criticism.

Again, the New Jersey Commission says that it is "convinced that the best results are to be achieved by the establishment of a permanent State Commission on Industrial Education, with local boards of trustees *independent of the present boards of education*, and appointed by the executive heads of the various municipalities."

There are other methods, such as the half-time projects, which might be undertaken to accomplish the same ends; but it is only after an exact determination of facts and careful discussion that any good at all will come out of it.

It is the facts that are needed first. No self-constituted body can adequately collect these on a broad enough basis to render its conclusion accepted without question. There should be appointed by the city or by the State government a commission similar to the Massachusetts Commission on Industrial Education, with sufficient power to investigate the entire question. After such a commission has made its preliminary report and determined as to the exact conditions to be met, its power should be sufficiently enlarged on lines which the report should indicate to place the control of all such public education in the hands of this commission.

No attempt has been made here to call attention to the great progress made in such investigations in different parts of the United States and abroad, nor has it been attempted to recite the experiments made in the training of artisans abroad, many of which are very successful.

If the author has succeeded in calling attention to the necessity of immediate action in our own city in a matter that is as vital to the

American boy as to the community, the object of this paper has been accomplished.

APPENDIX.

The following inquiries refer to ordinarily prosperous times and not necessarily to present conditions:

Machinists:

Number of all-around machinists in works..............................
Number of single-tool machinists.....................................
Number of apprentice machinists......................................
Number of boys not apprentices in machine shops......................
Number of boys not apprentices in machine shops......................
Name and position of the man directly in charge of apprentices, if any one...

Foundrymen:

Number of all-around foundrymen......................................
Number of foundry "specialists"......................................
Number of apprentices in foundry.....................................
Number of boys not apprentices in foundry............................
Name and position of the man directly in charge of apprentices, if any one...

Pattern-makers:

Number of pattern-makers...
Number of apprentices..

Boilermakers:

Number of all-around boilermakers....................................
Number of apprentices in boiler work.................................
Number of boys not apprentices in boiler work........................

What is the term of apprenticeship?......................................
About how many men complete their apprenticeship yearly?.................
On what basis are apprentices selected?..................................
If there are different classes of apprentices, please indicate difference, and if possible, divide into classes in the above list...........................
If you have printed regulations, indentures, agreements, etc., governing apprentices, will you not give me a copy of them and any other printed matter you use in this connection?...
Are these apprentices required to attend school, or to do any studying? Is such work done in the firm's time or outside?..........................
Do you have a satisfactory way of controlling what a student is supposed to study, or does he select for himself?.....................................

Signed........................

Dated........................

PAPER NO. 1070.

SANITARY CONTROL OF FILTER PLANTS.

FRANCIS D. WEST.

(Visitor.)

Read May 1, 1909.

BY the term "sanitary control of filter plants" we mean the operation of filter plants controlled by the results obtained from a laboratory where the sanitary quality of the water, as delivered to the consumer, is carefully tested by practical bacteriological tests.

Laboratories are maintained by the Bureau of Water of the city of Philadelphia at Belmont and at Torresdale. Duplicate tests are made daily of all raw and filtered waters; the effluents of all filters and samples of water collected from taps in all parts of the city. These determinations are made for the purpose of keeping the department posted as to the exact condition of the filtered water, and to inform the engineers in charge of the plants just what each individual filter is doing, so that it can be operated at its highest efficiency.

The Belmont Laboratory tests water from the two Roxborough plants and from the Belmont Filter Station. The Torresdale Laboratory tests water from the Torresdale Filter Station—the largest plant in the world, comprising 120 preliminary or roughing filters and 65 final or finishing filters; a total acreage of fifty-two.

What do we accomplish by filtration? We remove suspended matter, both organic and inorganic, for the principal purpose of removing pathogenic bacteria. Organic matter may consist of refuse, both vegetable and animal, decayed leaves, fibers, coal dirt, etc., micro-organisms, and bacteria. The inorganic material usually removed consists of clay and silt.

The filters remove this material in four ways:

1. By straining, in which the efficiency depends upon the size of the pores of the filter. A filter of fine uniform sand will have a better straining action than a filter of coarser material.

2. By adhesion, or the sticking of the impurities to the filtering substances or to other material already caught.

3. By sedimentation or settling out of the impurities within the pores or on the surface of the filter. This sedimentation is largely

responsible for the formation of the "Schmutzdecke" or dirt layer on the surface of the filter. This "Schmutzdecke" is the principal purifying agent in the slow sand or English system of filtration which is used in Philadelphia.

4. By biological and chemical action, including oxidation and the destruction of the organic pabulum and bacteria. This is the most important action of a filter, and takes place largely in the Schmutzdecke. That the action of a filter is in part an oxidizing process is shown by the decrease of the free and albuminoid ammonia and oxygen consumed (permanganate test), and the oxygen dissolved in the water. The amount of nitrates and carbon dioxid is increased. The temperature of the water is an element in bringing about this action, and may be the cause of the greater efficiency of filters during the warmer months.

The efficiency of a filter depends upon several elements, the principal of which are the influence of:

1. The size and uniformity of the sand. The finer the sand, the better the filter effluent and the shorter the run of service. A filter should contain a sand of low coefficient of uniformity. The sand in the preliminary filters at Torresdale has an effective size of .80 to 1.0 mm. and a coefficient of uniformity of 1.50 to 1.75. The rate of filtration reaches 80,000,000 gallons per acre per day. The sand in the final or finishing filters has an effective size of .25 to .35 mm. and a coefficient of uniformity of 1.5 to 2.5. The maximum rate is 6,000,000 gallons per acre per day.

2. The thickness of the sand layer. The filters at Torresdale contain from 26 inches to 40 inches of sand. As a general rule, a thick sand layer is more effective than a thin one. When a filter is in proper working order, a layer of 15 inches of sand will filter almost as effectively as a layer of 40 inches; but if the rate is changed suddenly, or if, from any cause, the Schmutzdecke is broken, the amount of dirty water getting through the 40-inch sand layer will be considerably less than that which will pass through the 15-inch layer, due to the greater resistance of the sand in the first case. Moreover, on account of this resistance a second or subsurface Schmutzdecke may form in the 40-inch layer.

3. The rate. With an increasing rate the efficiency decreases, due to the forcing through of material which might have been caught at a lower rate, and also to the fact that biological action has a shorter time in which to work. The rate should be equal in all parts of the

filter and should not be increased suddenly. The sand in the filter should be kept as level as possible.

4. Loss of head. With a low head the rate should be low. A filter should be started at a low rate, say, ¼ to ½ million gallons per acre per day. It should be increased with increased head, and decreased again when the loss of head is high. With a high loss of head and a high rate, the Schmutzdecke is liable to be broken, which will cause a sudden drop in the efficiency.

5. Ripeness. The fifth element is ripeness or aging of a filter. When a filter is new, or after the sand has just been restored, the biological action is nearly absent; and before the filter can do effective work, it is essential that the pores fill with organic matter so that biological action can take place. While the Schmutzdecke does most of the work of a filter, it does not do all, as is shown by the following series of tests made on a filter that had been long in service.

Sample 1	Schmutzdecke	80,000,000 bacteria per gram.
2	6″ below surface	80,000 " " "
3	8″ " "	22,000 " " "
4	12″ " "	6,000 " " "
5	14″ " "	5,800 " " "
6	16″ " "	5,700 " " "
7	18″ " "	5,800 " " "
8	20″ " "	5,400 " " "

The filter had been delivering a water with a count (gelatin plate) of below 20 per cubic centimeter, yet 20 inches below the surface the sand had a count of 5400 bacteria per gram.

Sterile sand was experimented upon at Lawrence, Mass., and in Germany, and the effluent contained more bacteria than the applied water, probably because the organic matter was in condition to be readily assimilated by the bacteria, causing them to multiply rapidly. The influence of temperature has already been mentioned.

There are five essentials in filtration. In order of importance they are:

1. The character of the effluent as shown by the death-rate.
2. The character as shown by simple bacterial purity.
3. The quality from a standpoint of clearness.
4. The quality with reference to the amount of soap used in the community.
5. The effect with reference to the incrustation of boilers.

What has been done in Philadelphia by filtration toward reducing typhoid is shown by Plates I and II.

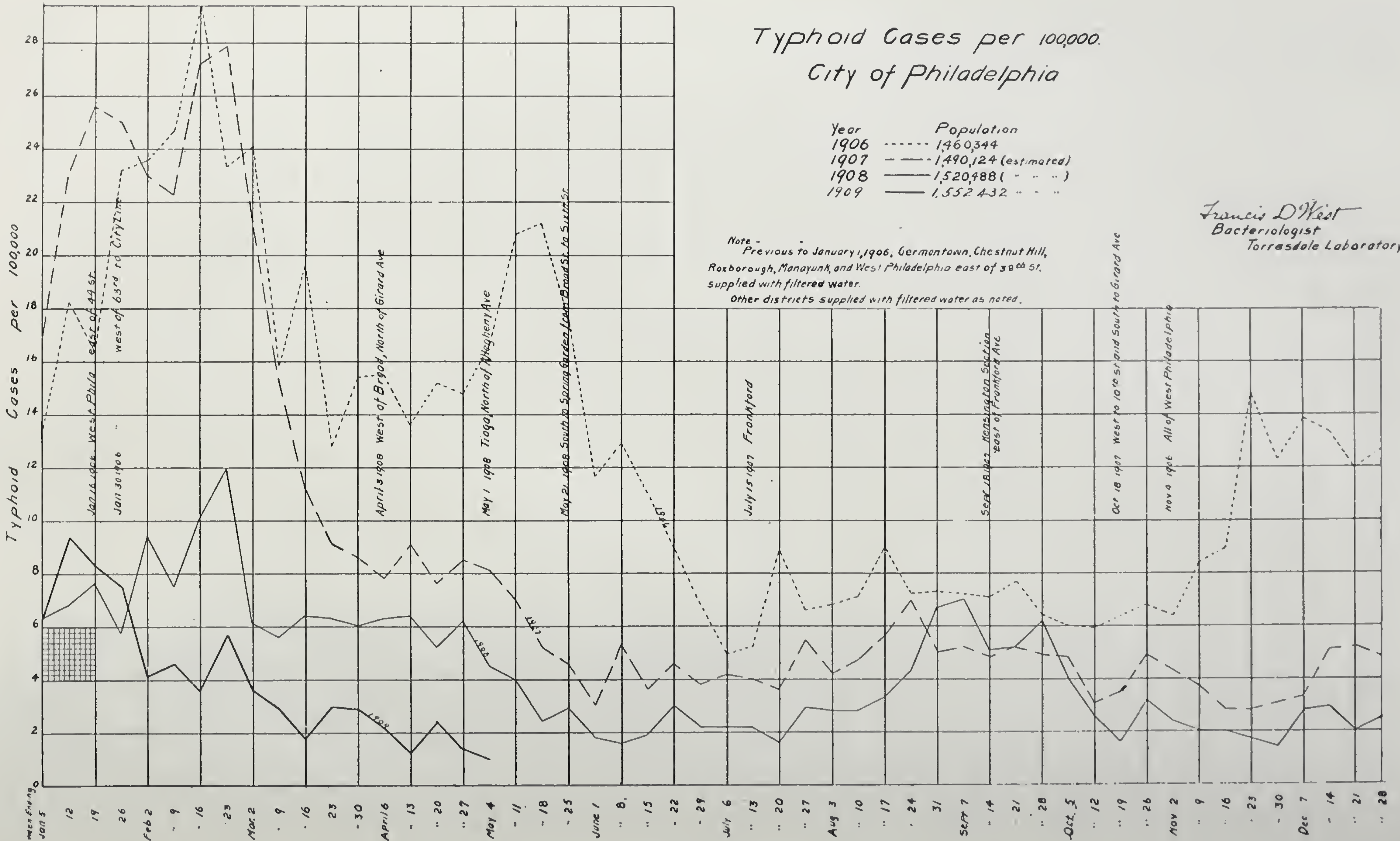
Typhoid Cases per 100,000.
City of Philadelphia
Year Population
1906 1,460,344
1907 1,490,124 (estimated)
1908 1,520,488 (" " ")
1909 1,552,432 " " "
Note -
Previous to January 1, 1906, Germantown, Chestnut Hill, Roxborough, Manayunk, and West Philadelphia east of 38th St. supplied with filtered water.
Other districts supplied with filtered water as noted.
Francis D. West
Bacteriologist
Torresdale Laboratory
Typhoid Cases per 100,000
Jan 16 1906 West Phila east of 44 St.
Jan 30 1906 west of 63rd to City Line
April 3 1908 West of Broad, North of Girard Ave
May 1 1908 Tioga North of Allegheny Ave
May 21 1908 South to Spring Garden from Broad St. to Sixth St.
July 15 1907 Frankford
Sept 18 1907 Kensington Section east of Frankford Ave
Oct 18 1907 West to 10th St and South to Girard Ave
Nov 4 1906 All of West Philadelphia
Week Ending Jan 5

Plate I.

In 1906 West Philadelphia, Germantown, Chestnut Hill, Roxborough, and Manayunk were receiving filtered water. The Torresdale Filter Plant was started July 4, 1907, and began delivering 40,000,000 gallons of water a day to Frankford on July 15th. Almost immediately the change was perceptible. The number of cases of typhoid from

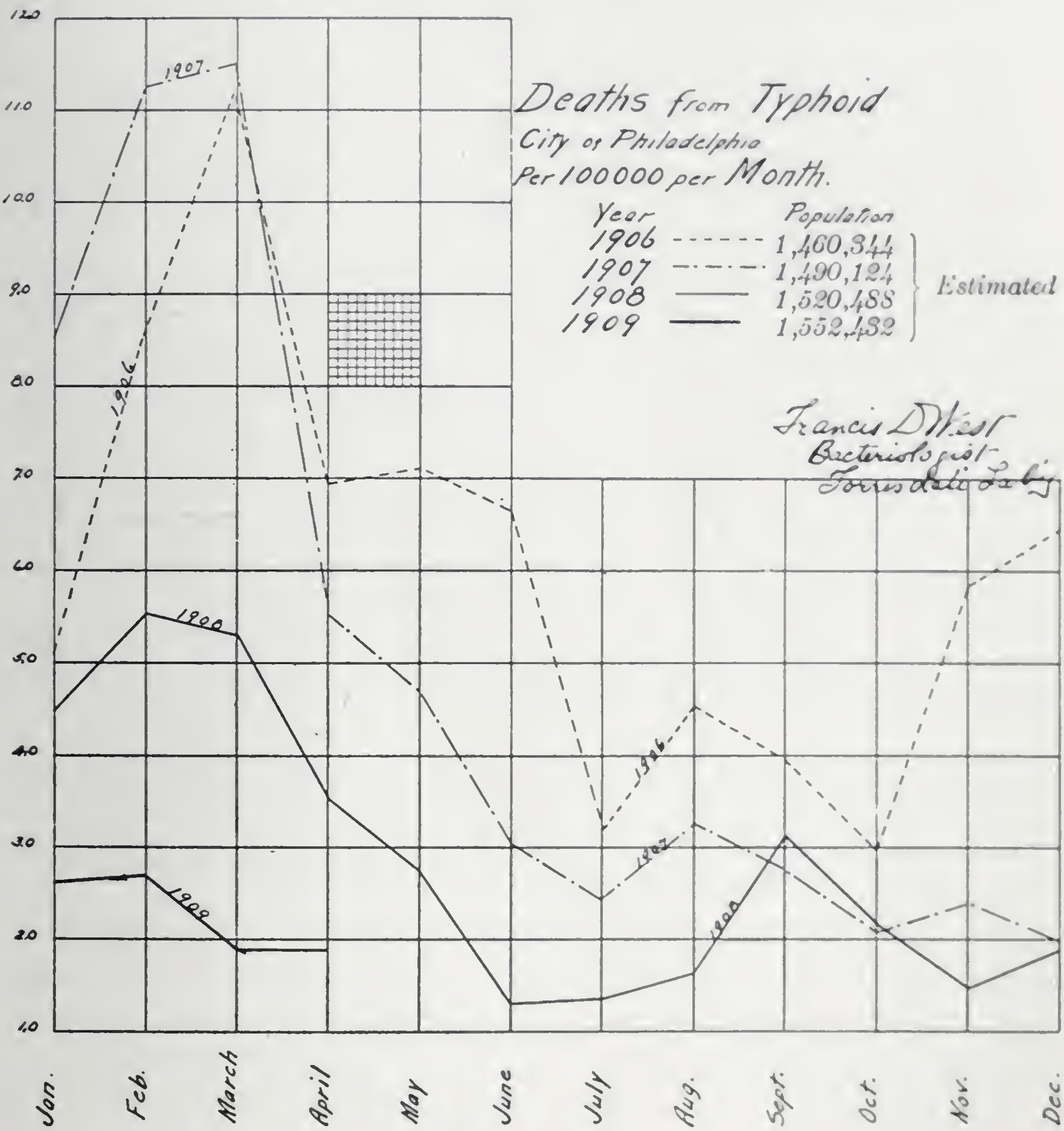

PLATE II.

this district, which was at this time the worst in the city, and which had been receiving unfiltered Delaware River water, took a decided drop. The output from Torresdale was gradually increased as shown on Plate I until February 28, 1909, when the entire city received filtered water, and the output reached 210,000,000 gallons a day, or

over 6,000,000,000 gallons a month. It has since been increased to 230,000,000 gallons.

The deaths from typhoid in 1906 were 1061, in 1907 were 888, in 1908 were 533, and in 1909, judging from the number of deaths during the first three months, when the rate is usually highest, the number should not exceed 400—a rate of about 25 per 100,000, compared with 72.6 in 1906, 59.7 in 1907, and 35.0 in 1908.

The normal typhoid death-rate in Philadelphia is at least 15 per 100,000. By normal typhoid is meant typhoid from sources other than the water-supply. Other sources of typhoid are oysters, uncooked vegetables, milk, ice, flies, contaminated wells, bottled waters, and secondary infection.

Oysters.—Several epidemics due to oysters are well known. Notably at Wesleyan University, at Lawrence, Long Island, and at Southhampton, England. That the typhoid bacillus in oysters is not killed by ordinary methods of cooking is shown by the Report of the Massachusetts State Board of Health for 1905. Philadelphia is a large consumer of oysters. That New Jersey oysters are often sewage-fed is shown by the protests of the oyster planters, and by the steps that the New Jersey State Board of Health is taking to protect the oyster industry.

Uncooked Vegetables.—Uncooked vegetables, especially lettuce and celery fertilized with night soil, have frequently caused typhoid, as at Springfield, Mass., in 1905.

Milk.—Although Philadelphia's milk-supply compares favorably with most cities, yet many cases could doubtless be traced to this cause. One milkman could cause an epidemic, as did happen at Springfield, Mass., Montclair, N. J., and Waterbury, Conn.

Ice.—Typhoid bacteria have been known to live in ice for a long time. Ice itself can be free from the germs, but cracked ice used in clubs and restaurants, when handled by unclean hands, may be an element of danger. An epidemic caused by ice occurred at Ogdensburg, N. Y.

Flies.—The legs and body of a fly are capable of carrying countless bacteria. Mr. Daniel D. Jackson, Director of Mt. Prospect Laboratory, Brooklyn, has published an article, "The Pollution of New York Harbor as a Menace to Health by the Dissemination of Intestinal Diseases through the Agency of the Common House-fly." In this article he shows conclusively that in New York, in the summer, not only typhoid but other intestinal diseases numbering many thousand cases are caused by the fly. He condemns the sanitary condition of

the wharves of New York. Philadelphia, too, could stand a little house-cleaning along the river front.

Wells.—In the lower end of Kensington and Richmond old wells, probably badly contaminated, are still in existence.

Bottled Waters.—To the average person a clear water is a pure water. Are we sure that the numerous brands of so-called pure waters are pure; and that the bottles have been thoroughly cleaned and sterilized before filling?

Secondary Infection.—Doubtless many cases of typhoid are caused by secondary infection, but as the number of primary cases has decreased the number of secondary cases has decreased as well.

Water-supply gets the blame for all typhoid, but at least 15 cases per 100,000 can be attributed to the above causes. An allowance of $10,000 per death—which includes ten cases for each death, doctor bills, loss of services, cost of nursing, medicine, funerals—will be found low. If there will be 400 deaths from typhoid in 1909, 650 deaths will have been saved as compared with 1906, nearly 500 as compared with 1907, and 133 as compared with 1908. This means, in the first case, a saving of $6,500,000 per annum or $4.00 per capita—enough to pay for the entire filtration system in less than four years.

What has been accomplished in the way of bacterial purity and clearness is shown by the laboratory report sheets printed in the annual report of the Bureau of Water. A portion of one is here given.

TABLE No. 1.

CITY OF PHILADELPHIA, BUREAU OF WATER, TORRESDALE LABORATORY; REPORT OF THE LEADING DAILY RESULTS FROM TORRESDALE FILTERS.

For the Week Ending Saturday, 12.00 Midnight, April 17, 1909. Approved by Francis D. West, in charge.

Results from.	Day of Week.	Bacteria per Cubic Centimeter.	Parts per Million.										Percentage Removed.	
			Turbidity, Silica Standard.	Total Solids.	Suspended Matter.	Nitrogen as: Total Organic and Ammonium.	Nitrogen as: Nitrites.	Nitrogen as: Nitrates.	Oxygen Consumed.	Chlorine.	Iron.	Color.	Bacteria.	Turbidity.
Applied Water, Preliminary Filters.	Sun. 11	1400	14	..	..	..	..	..	..	..	..	..	..	
	Mon. 12	620	11	..	..	..	..	..	..	..	..	..	..	
	Tues. 13	1200	17	89	48	.36	.003	.40	3.15	1.8	1.64	15	..	
	Wed. 14	3000	28	..	..	..	..	..	..	..	..	..	..	
	Thurs. 15	21000	38	..	..	..	..	..	..	..	..	..	..	
	Fri. 16	10000	45	..	..	..	..	..	..	..	..	..	..	
	Sat. 17	4300	32	..	..	..	..	..	..	..	..	..	..	
	Average	5900	26	..	..	..	..	..	..	..	..	..	..	
	Percentage Removed	..	..	..	..	..	..	..	..	..	..	..	..	

TABLE No. 1.—(*Continued.*)

Results from.	Day of Week.	Bacteria per Cubic Centimeter.	Parts per Million. Turbidity, Silica Standard.	Total Solids.	Suspended Matter.	Nitrogen as Total Organic and Ammonium.	Nitrites.	Nitrates.	Oxygen Consumed.	Chlorine.	Iron.	Color.	Percentage Removed. Bacteria.	Turbidity.
Applied Water, Final Filters.	Sun. 11......	190	1	..	..	..	..	..	..	..	..	..	86.4	92.9
	Mon. 12......	230	1	..	..	..	..	..	..	..	..	..	62.9	90.9
	Tues. 13.....	560	2	42	..	.23	.008	.35	2.05	..	..	..	53.3	88.2
	Wed. 14.....	520	3	..	..	..	..	..	..	..	..	..	82.7	89.3
	Thurs. 15....	4500	26	..	..	..	..	..	..	..	..	..	78.6	31.6
	Fri. 16.......	3300	30	..	..	..	..	..	..	..	..	..	67.0	33.3
	Sat. 17......	1600	20	..	..	..	..	..	..	..	..	..	62.8	37.5
	Average.....	1600	12	..	..	..	..	..	..	..	..	..	..	..
	Percentage Removed..	72.9	53.8	53.0	..	36.0	—167.	12.	35.	..	..	..	..	..
Filtered Water Basin.	Sun. 11......	29	0	..	..	..	..	..	..	..	..	..	97.9	100
	Mon. 12.....	16	0	..	..	..	..	..	..	..	..	..	97.4	100
	Tues. 13.....	22	0	..	..	..	..	..	..	..	..	..	98.2	100
	Wed. 14.....	24	0	45	..	.14	.000+	.48	1.70	..	..	..	99.20	100
	Thurs. 15....	41	0	..	..	..	..	..	..	..	..	..	99.80	100
	Fri. 16.......	34	0	..	..	..	..	..	..	..	..	..	99.66	100
	Sat. 17.......	30	0	..	..	..	..	..	..	..	..	..	99.30	100
	Average.....	28	0	..	..	..	..	..	..	..	..	..	..	..
	Percentage Removed..	*99.53	100	49.4	..	61.2	100	—20	46.1	..	..	..	..	..
Lardner's Point Pumping Station.	Sun. 11......	..	..	..	..	..	..	..	..	..	..	..	..	..
	Mon. 12......	80	0	..	..	..	..	..	..	..	..	..	87.1	100
	Tues. 13.....	42	0	..	..	..	..	..	..	..	..	..	96.5	100
	Wed. 14.....	—	0	..	..	..	..	..	..	..	..	..	..	100
	Thurs. 15....	100	0	..	..	..	..	..	..	..	..	..	99.52	100
	Fri. 16.......	35	0.5	..	..	..	..	..	..	..	..	..	99.65	98.9
	Sat. 17.......	37	0	..	..	..	..	..	..	..	..	..	99.14	100
	Average.....	*59	0	..	..	..	..	..	..	..	..	..	..	..
	Percentage Removed..	99.20	100	..	..	..	..	..	..	..	..	..	..	..
Effluent Filter 1	Sun. 11......	16	0	..	..	..	..	..	..	..	..	..	91.6	100
	Mon. 12......	14	0	..	..	..	..	..	..	..	..	..	93.9	100
	Tues. 13.....	15	0	..	..	..	..	..	..	..	..	..	97.3	100
	Wed. 14.....	20	0	..	..	..	..	..	..	..	..	..	96.2	100
	Thurs. 15....	34	0	..	..	..	..	..	..	..	..	..	99.24	100
	Fri. 16.......	28	0	..	..	..	..	..	..	..	..	..	99.15	100
	Sat. 17.......	18	0	..	..	..	..	..	..	..	..	..	98.9	100
	Average.....	21	0	..	..	..	..	..	..	..	..	..	..	..
	Percentage Removed..	98.7	100	..	..	..	..	..	..	..	..	..	..	..
Effluent Filter. 2	Sun. 11......	20	0	..	..	..	..	..	..	..	..	..	89.5	100
	Mon. 12......	22	0	..	..	..	..	..	..	..	..	..	90.4	100.
	Tues. 13.....	—	—	..	..	..	..	..	..	..	..	..	—	—
	Wed. 14.....	28	0.5	..	..	..	..	..	..	..	..	..	94.6	83.3
	Thurs. 15....	54	0.5	..	..	..	..	..	..	..	..	..	98.8	98.1
	Fri. 16.......	27	0	..	..	..	..	..	..	..	..	..	99.18	100
	Sat. 17.......	30	0	..	..	..	..	..	..	..	..	..	98.1	100
	Average.....	30	0	..	..	..	..	..	..	..	..	..	..	..
	Percentage Removed..	98.2	100	..	..	..	..	..	..	..	..	..	..	..

* Percentage Removed at Filtered Water Basin and Lardner's Point is that of entire plant.

The bacterial count is well below the German standard of 100 bacteria per cubic centimeter, and the percentage of removal of the plants is over 99. Bacillus coli communis is nearly always absent. The filtered water is always clear and the days when liquid coal was delivered for water have passed. These facts will save the citizens money, because the amount of bottled water purchased will be less when the people begin to have more faith in filtered water.

Soap Used.—At present 230,000,000 gallons of Delaware River water are used per day where 40,000,000 were used in 1906; that is to say, 190,000,000 gallons of Delaware River water replace as many gallons of Schuylkill. According to Whipple,* the depreciation due to hardness per part per million is $10 per million gallons. If we say one gallon out of every hundred is softened, then 1.9 million gallons per day Delaware River are softened when formerly the same number from the Schuylkill were used. If we soften 1.9 million gallons of a hardness of 58 parts per million instead of a hardness of 99 parts, we save 41 parts, or $410 per million gallons, or $780 per day, or about $280,000 per annum. This is for soap alone, not counting labor, which is worth at least as much more.

Boiler Incrustation.—The permanent hardness of the Delaware River is less than one-half that of the Schuylkill, as is shown by Table No. 2. The boiler incrustation likewise should not be over half.

TABLE No. 2.

Month, 1908.	Delaware River.			Schuylkill River.		
	Sulphates as SO_3.	Alkalinity as $CaCO_3$.	Hardness as $CaCO_3$.	Sulphates as SO_3.	Alkalinity as $CaCO_3$.	Hardness as $CaCO_3$.
January	9	20	48	26	38	84
February	8	22	48	20	36	68
March	7	16	45	23	31	68
April	7	19	42	30	45	66
May	8	20	37	25	36	64
June	9	35	55	33	55	100
July	12	45	70	34	58	105
August	11	42	68	27	63	101
September	13	45	74	44	75	129
October	16	51	80	47	73	136
November	11	31	61	48	66	135
December	12	33	64	46	60	131
Average	10 †	32	58	34	53	99

* "Value of Pure Water," by G. C. Whipple.

† Parts per million.

[Note: I desire to thank Mr. Fred. C. Dunlap, Chief of Bureau of Water, for permission to use department records previous to their publication by him in his Annual Report.—Francis D. West, *Chemist in Charge Torresdale Laboratory.*]

DISCUSSION.

In reply to questions Mr. West made the following statements:

The filtered water basin is covered and holds 50 million gallons.

The methods used in the laboratories of the Bureau of Water are those of the American Public Health Association. They are standard methods and have been adopted by all the leading laboratories in the country, although each operator makes some slight variations according to his own ideas.

We cannot immediately determine the quality of water a filter is delivering. One of our methods will give us data in eighteen hours, but our ordinary gelatin count which we use for routine work requires forty-eight hours' incubation. The bacteria must grow into colonies before we can count them. We have sixty-five filters at Torresdale, and if one is giving a poor effluent we will check it up in two days. As to the effect of this water on the general output of the plant, when a filter is put back into service after cleaning, it at first may deliver a water somewhat below the standard. The filters at Torresdale are started at a half million rate. At this rate a filter will deliver 375,000 gallons in twenty-four hours, as each filter has a net area of $\frac{3}{4}$ acre. The present output of the plant is 230 million gallons daily, of which the 375,000 gallons is but .12 per cent. The influence of a single filter under these conditions would not be marked. If a break should occur in a filter running at a high rate, the amount of water of inferior quality would be greater, being about 2 per cent. of the output in the case of a filter running at the maximum rate of six million gallons per acre daily. As soon as discovered an inferior effluent is turned into drains provided for wasting the effluent.

In starting filters after cleaning the following schedule of rates is observed as far as practicable:

48 hrs.	.5	million	gallons	per	acre	daily	rate
48 "	1.	"	"	"	"	"	"
48 "	2.	"	"	"	"	"	"
24 "	3.	"	"	"	"	"	"
24 "	4.	"	"	"	"	"	"
24 "	5.	"	"	"	"	"	"
Then at a	6.	"	"	"	"	"	"

which is maintained until the maximum loss of head is reached, when the filter is cleaned and a new run started.

Before we had the preliminary filters we considered a yield of 30 million gallons between cleanings a good run. With pre-filtered water we get yields as high as 400 million gallons. The length of the run varies with the condition of the raw water and the season. Next summer we may reach a yield of 500 million gallons per run.

Again, the demand for water in the city varies. We cannot count on delivering the same quantity of water day after day. The clear water basin is a storage reservoir and a regulator for the plant; rise or fall in that basin serves as a guide to decrease or increase the output from the filters, as the case may require. This is done by changing rates of individual filters.

The entire 120 preliminary filters at Torresdale have been in service since about March 1, 1909. The time is too short to tell just what the ultimate results of these filters will be. It is expected that they will on an average remove about 70 per cent. of the dirt that caused the short runs on the final filters. We have better control of the filters than before and are never hard pressed to meet the demand on the plant, although it is now delivering double the quantity we were able to filter before the preliminary filters were finished. To replace the preliminary filters would necessitate a sedimentation basin holding over 800 million gallons. The sedimentation obtained by such a basin might be 60 per cent. and it might not.

No coagulants of any kind are used at any of the filter plants operated by the Bureau of Water.

I think it is an advantage to keep the depth of sand uniform. Take a bed with a 40-inch sand layer. By scraping and ejecting it might be reduced to a thickness of 16 inches before it became practicable to re-sand, but by other methods—for example, washing the sand in the bed—the clean sand is returned at once to the bed and the same thickness of sand layer is maintained for all runs. I think that this feature is important, for the efficiency is not entirely due to the work done by the top layer or "Schmutzdecke," but also to the sand below it. There is an advantage in addition to this: if for any cause the "Schmutzdecke" is broken, it is more probable that a thick bed will retain the bacteria than a thin one.

In any comparison of Philadelphia, with, say, 25 deaths per 100,000 per annum, which is a fairly high estimate, it must be borne in mind that filtered water was not supplied to the entire city until March 1st, so the cases contracted during the first two months of the year will increase the deaths for 1909. For a fair comparison of a year's run with filtered water the record of deaths should run from May 1, 1909, to May 1, 1910, during which period I think the rate will not be over 20 per 100,000.

With reference to the possible contamination of the water through leakage into the Torresdale conduit, I might say that I was one of the men sent into the conduit to find how much contamination was getting in. We sampled all the leaks and tested them bacteriologically, and in almost every case the water had a very low count. The water after filtering through the soil above the conduit was almost sterile. After the Torresdale plant had been in operation for six months, I compared results from the filtered water basin with those from Lardner's Point Pumping Station at the lower end of the conduit, and found that, averaging the first six months' run, the water was practically the same at both places. It is my opinion that if there are any leaks they are outward and not inward. The volume in the conduit is displaced twenty-five times a day. The infiltration would be small, if any, and from our results the leaks do not contaminate the water.

The following table, which has been compiled from data published by the respective Boards of Health, shows where Philadelphia stood in the years 1900 to 1907 inclusive:

Table showing Typhoid Deaths per 100,000 per Annum for Eight Years, 1900 to 1907 Inclusive.

Jersey City, N. J	17
New York, N. Y	18
Providence, R. I	19
Newark, N. J	19
Detroit, Mich	19
Milwaukee, Wis	20
Boston, Mass	21
Brooklyn, N. Y	22
Chicago, Ill	25
Buffalo, N. Y	28
St. Louis, Mo	28
Baltimore, Md	36
New Orleans, La	41
Indianapolis, Ind	42
Cleveland, O	42
Philadelphia, Pa	52
Cincinnati, O	53
Washington, D. C	55
Louisville, Ky	56
Pittsburg, Pa	130

E. G. Perrot.—In going through a plant in this city recently I noticed a number of boiler-tubes with a large amount of incrustation. The engineer in charge thought the effect of filtered water would probably make the incrustation worse; in fact, he said that after they had filtered water the tubes were worse than before.

Mr. West.—Turbidity is due to the stirring up of the dirt that is in the pipes. Considerable dirt is lodged in them from the water previously furnished to the city. There is no question but that bacteria are in the dirt in the pipes. I have been testing samples of water from Twelfth and Columbia Avenue for the greater part of a year past. The water from that part is very clear and the bacteria count is very low. On March 20th the pressures were markedly increased in that district, and the count for a sample from that point ran up to 1800 per cubic centimeter. This was due to stirring up the dirt in the pipes. Some of the older pipes are heavily incrusted, and any operation of valves causing increased flow or changing of direction will stir up the dirt. It is not due to any chemical change.

I doubt if there was any increase in incrustation of boilers after filtered water from the Delaware River was turned into the city mains, because the things which cause incrustation of boilers have been decreased and taken out of the water.

President Dallett.—In regard to Mr. Perrot's view, I think it is reasonable to suppose that on account of the alluvial deposits in the mains we get substances

in the water which make a softer scale than the deposit from the clear water that is now being furnished, and the softer the scale the easier it is to remove.

Mr. West.—I agree with President Dallett in that the "alluvial deposits" in the mains might make a softer scale than the kind deposited from the clear water now furnished. A supply of 190 million gallons per day of water softened by 41 parts per million has been substituted for the water previously furnished, the permanent hardness due to sulphate of lime is therefore less than one-half of the previous Schuylkill supply. This 190-million-gallon supply went chiefly into the Kensington mill district, where there are many factories, and mills, and it is there where I think the change will be felt. Do not confuse this with the West Philadelphia district, where the supply is from the Schuylkill, and there the scale may be harder than before.

ABSTRACT OF MINUTES OF THE CLUB.

Business Meeting, February 6, 1909.—President Dallett in the chair. One hundred and nine members and visitors were in attendance.

A letter from Mr. Martin Nixon Miller, active member of the Club, describing conditions on the Panama Canal zone, was received, and posted on the bulletin board.

The Tellers reported the election of John Edwin Fulweiler and Chauncey Graham Helick to active membership; Albert Main Gregory, Frederick Haag, Jr., Frederick Newlin Price, and Edward Riegle Snyder to junior membership; and George Sumner Crampton to associate membership.

Mr. T. J. Litle, Jr., visitor, presented a paper on "Recent Improvements in Gas Lighting Apparatus," which was discussed by Messrs. William Easby, Jr., George C. Davis, Emile G. Perrot, E. M. Nichols, Carl Hering, A. H. Allen, and others.

Business Meeting, February 20, 1909.—President Dallett in the chair. One hundred and five members and visitors were in attendance.

It was announced that at the meeting of the Board of Directors, held February 20th, Mr. Washington Jones, active member of the Club, had been unanimously elected to Honorary Membership.

The several proposed amendments to the By-Laws, which had been presented at the meeting of January 2d, in accordance with the By-Laws, were presented to the Club for discussion, but no amendments were offered.

The evening was devoted to an open discussion on "Topics Connected with the Disposal and Purification of Sewage," which was opened by Mr. F. Herbert Snow, of Harrisburg, Pa. The discussion was also participated in by Dr. Henry Leffmann and Messrs. Howard Murphy, S. M. Swaab, William Easby, Jr., P. A. Maignen, George R. Stearns, George S. Webster, David W. Horn, Alfred Priestman, John C. Trautwine, Jr., and others.

Business Meeting, March 6, 1909.—President Dallett in the chair. One hundred and fifty-five members and visitors were in attendance.

The Tellers reported that St. John Chilton, Arthur S. Garrett, and M. D. Sidney Stiles were elected to active membership; that Francis Royal Berlin, Franklin Forrest Dickerman, Charles Taylor Myers, William John Pollock, and Thomas Joseph Reilly were elected to junior membership; and that J. Reese Bailey and Henry A. Moore were elected to associate membership.

The Tellers also reported the following as the result of the balloting on the several amendments to the By-Laws affecting the status of Associate Members: Total legal ballots cast, 128; for the amendments, 103; against the amendments, 25; necessary for approval, 86.

Mr. Manton E. Hibbs presented a paper, entitled "Hammerstein as a Builder," describing the construction of the Philadelphia Opera House. The paper was

discussed by Messrs. Walter F. Ballinger, Henry H. Quimby, S. M. Swaab, E. M. Nichols, George C. Davis, Wm. Easby, Jr., and others.

Regular Meeting, March 20, 1909.—President Dallett in the chair. Eighty-two members and visitors in attendance.

The President announced that a Committee on the revision of the By-Laws had been appointed to harmonize a number of existing contradictions and ambiguities, and requested that any members of the Club who had suggestions to make in this regard should forward same to one of the members of the Committee. The members of the Committee are William Easby, Jr., J. O. Clarke, and William S. Twining.

It was also announced that a vote on permitting smoking in the meeting-room would be taken at the following meeting.

The death of Mr. Alexander Murrie, active member of the Club since December 21, 1907, was announced. Mr. Murrie's death occurred on March 19, 1909.

The Secretary read a report from the Chairman of the Reception Committee, announcing that a general meeting of the sub-committees would be held on Monday evening, March 29th, and a statement was also made that the reception will probably be held on Friday evening, April 30th.

Mr. George H. Benzon, Jr., active member, presented the paper of the evening, entitled "Metal Planing Machines," which was followed by a short discussion by Mr. Francis Head, Mr. Benzon, and the President.

Business Meeting, April 3, 1909.—President Dallett in the chair. One hundred and eighty members and visitors in attendance.

The question of permitting smoking during meetings was brought up for consideration, and, after considerable discussion, it was moved that the question be laid upon the table, and was carried by a vote of 64 to 29.

The Tellers of Election reported, showing that 121 legal ballots had been cast, and that George Amandus Buvinger, Hamilton Eugene Hutchins, Robert Bruce Lewis, and B. B. Milner were elected to Active Membership; that David S. Thompson and Clarence E. Wunder were elected to Junior Membership, and that Edward Foggs Cobb was elected to Associate Membership.

Mr. J. O. Clarke, Chairman of the Reception Committee, announced that the Ladies' Reception would be held on Friday, April 30th, and requested that members notify the Committee at once of their intention to be present or not.

The paper of the evening, entitled "Wireless Telegraphing and Telephoning," was presented by Mr. A. Fred Collins, visitor, and consisted of a demonstration of certain forms of apparatus used in this connection. It was followed by a short discussion by Messrs. Snook, Hering and others. Upon motion of Mr. Trautwine, a vote of thanks was extended to Mr. Collins.

Business Meeting, April 17, 1909.—President Dallett in the chair. Ninety members and visitors in attendance.

The Secretary announced that the resignations of Mr. August A. Miller, Mr. E. P. Coles, and Mr. Lewis F. Moody had been received and accepted by the Board of Directors.

The report of the Committee on Rules on the proposed revision of the By-Laws was presented.

Mr. Benjamin Franklin, active member, presented the paper of the evening, entitled "Interurban Railways," which was followed by a discussion by Messrs. E. M. Nichols, Thomas G. Janvier, C. J. Hopkins, John C. Trautwine, Jr., and Charles M. Mills.

ABSTRACT OF MINUTES OF THE BOARD OF DIRECTORS.

Special Meeting, February 6, 1909.—Present: President Dallett; Vice-Presidents Devereux and Easby; Directors Clarke, Head, Twining, Cochrane, Develin, Hess, Hutchinson, Mebus; the Secretary and the Treasurer.

It was decided to hold the regular Board meeting on the third Saturday of each month at 4 P. M.

The proposal to elect Mr. Washington Jones to Honorary Menbership was discussed, and, upon motion, the Secretary was instructed to issue a letter ballot, calling for a vote to elect Washington Jones to Honorary Membership, and, also, to call a special meeting February 13th, to canvass this ballot.

The resignation of Mr. George S. Cheyney, as alternate teller of election, was accepted, and Mr. E. J. Dauner was elected in his place.

Special Meeting, February 13, 1909.—Present: President Dallett; Vice-Presidents Devereux, Easby, Spalding; Directors Head, Christie, Cochrane, Develin, Hutchinson, Mebus; the Secretary and the Treasurer.

C. H. Ott and E. J. Dauner accepted positions as auditor and alternate teller.

The proposed election of Mr. Washington Jones to Honorary Membership was held over until the following meeting of the Board.

The resignation of Mr. R. T. Eaton was accepted, to date from January 1, 1909.

It was ordered that the Directory, in the future, be issued, corrected to the first of July.

The proposal to donate a complete set of the publications of the "Proceedings" to the Free Library of Philadelphia was referred to the Library Committee, with the power to act.

Regular Meeting, February 20, 1909.—Present: President Dallett; Vice-Presidents Washington Devereux and Wm. Easby, Jr.; Directors Christie, Cochrane, Hess, and Hutchinson; and the Secretary and the Treasurer.

The following appropriations were made to the various standing committees for the current year:

Library Committee	$50.00
House Committee	12,000.00
Meetings Committee	1,100.00
Publication Committee	300.00

Mr. Washington Jones was declared elected an Honorary Member, by a unanimous vote.

It was ordered that the Secretary and the Treasurer receive no salaries for the current year.

Regular Meeting, March 20, 1909.—Present: President Dallett, Vice-Presidents Devereux and Easby, Directors Clarke, Head, Cochrane, Develin, Hess, Gwilliam, Hutchinson, Mebus, Wood, Ehlers, and Taylor.

Mr. W. B. Riegner, Chairman of the Auditors, announced by letter eight errors in the accounts during the past month. The Treasurer reported explanations of the errors, as announced in Mr. Riegner's letter.

A petition was presented from the Junior Section, requesting that they be represented on the Membership Committee, on applications received for Junior Membership. As this, however, conflicted with the By-Laws, the petition was not approved.

A letter from Mr. J. Max Bernard was read, suggesting that the By-Laws provide for the creation of Life Memberships. This was referred to the Committee on Rules, for a report.

A letter from Mr. Washington Jones, accepting Honorary Membership, was read.

The death of Mr. Alexander Murrie, active member of the Club since December 21, 1907, was announced.

A letter was read from Mr. L. F. Rondinella, protesting against permitting smoking in the meeting-room, and, after discussion, it was decided to take a standing vote at the meeting of the Club on April 3d.

Mr. J. O. Clarke presented a progress report of the Badge Committee.

Regular Meeting, April 17, 1909.—Present: President Dallett, Vice-Presidents Easby and Spalding, Directors Clarke, Head, Quimby, Twining, Christie, Cochrane, Wood, Ehlers, and Taylor.

Mr. Christie reported for the Finance Committee, showing a favorable increase in the returns from the restaurant and lodgings.

The resignations of Mr. A. A. Miller, E. P. Coles, and Lewis F. Moody were accepted.

Mr. Easby, Chairman of the Committee on Rules, presented a report on the proposed revision of the By-Laws, which was discussed in detail, and, after amendment in several particulars, was adopted for presentation to the Club.

THE ENGINEERS' CLUB OF PHILADELPHIA

1317 Spruce Street

OFFICERS FOR 1909

President

W. P. DALLETT

Vice-Presidents

Term Expires 1910
WASHINGTON DEVEREUX

Term Expires 1911
WM. EASBY, JR.

Term Expires 1912
PHILIP L. SPALDING

Secretary
W. P. TAYLOR

Treasurer
H. E. EHLERS

Directors

Term Expires 1910	*Term Expires 1911*	*Term Expires 1912*
J. O. CLARKE	JAMES CHRISTIE	GEO. T. GWILLIAM
W. S. TWINING	HENRY HESS	EDW'D S. HUTCHINSON
FRANCIS HEAD	H. P. COCHRANE	CHARLES F. MEBUS
HENRY H. QUIMBY	RICHARD G. DEVELIN	A. C. WOOD

STANDING COMMITTEES OF BOARD OF DIRECTORS

House—W. S. Twining, Geo. T. Gwilliam, H. P. Cochrane, A. C. Wood, James Christie.

Finance—James Christie, Philip L. Spalding, Richard G. Develin.

Membership—Wm. Easby, Jr., Chas. F. Mebus, Geo. T. Gwilliam.

Publication—H. H. Quimby, Chas. F. Mebus, Francis Head.

Meetings—J. O. Clarke, Francis Head, A. C. Wood.

Library—Washington Devereux, H. P. Cochrane, Edw'd S. Hutchinson.

Publicity—George T. Gwilliam, W. P. Taylor, J. O. Clarke.

Advertising—H. E. Ehlers, H. P. Cochrane, Chas. F. Mebus.

MEETINGS

Annual Meeting—3d Saturday of January, at 8.15 P.M.

Stated Meetings—1st and 3d Saturdays of each month, at 8.15 P.M., except between the fourteenth days of June and September.

Business Meetings—When required by the Constitution or By-Laws, when ordered by the President or the Board of Directors, or on the written request of five Active or Associate Members of the Club.

The Board of Directors meets on the 3d Saturday of each month, except July and August.

PROCEEDINGS

OF

THE ENGINEERS' CLUB

OF PHILADELPHIA.

ORGANIZED DECEMBER 17, 1877. INCORPORATED JUNE 9, 1892.

Vol. XXVI. JULY, 1909. No. 3

PAPER NO. 1071.

METAL PLANING MACHINES.

GEO. H. BENZON, JR.

(Active Member.)

Read March 20, 1909.

A PLANING machine, as the name suggests, is one for developing plane surfaces in wood, metal, etc., through the agency of cutting tools, and is made in two forms, the reciprocating and the rotary. The latter form, as applied to the metal art, is very limited in its scope, unless one considers the milling or slabbing machine under this head. In view of this fact, and also that the milling machine is in a recognized separate division of machine tools, and is not usually included under planing machines, this paper will be confined to the reciprocating type.

Planers have gone through numerous changes in details of construction since the early part of the nineteenth century, when their history was in its infancy, but the process of passing the piece to be planed backward and forward under the cutting tools, and feeding the tools across the work, is the same now as then. In the meantime there have been and still are designers who advocate the reversal of the principle, by holding the work stationary and moving the tools; but the general and most practical method is the old one carried from the earliest designs.

Time and space will prevent detailed consideration of the modern

improvements, the principal elements furnishing sufficient matter for discussion.

The Driving Mechanism.—The first method used in imparting motion to the table or platen carrying the piece to be planed was in the nature of a rope, wound and unwound around drums at the end of the bed through the agency of a spider, or hand-wheel, and later by motive power. This method was soon superseded by the screw drive and the spur geared drive, the latter being used at the present day by numerous builders, the screw drive being practically obsolescent. The spur geared drive consists of one or more gears and pinions of the spur form used to make the necessary reduction in speed between the driving belt and the rack, and to drive directly into the rack. The wheel gearing with the rack is known as the bull wheel.

The longest step and the greatest improvement in driving gear was made about 1860 by Wm. Sellers & Co., when they introduced the "spiral geared drive"—since known as the "Sellers motion." This consists of a spiral or helical pinion, usually of four or five teeth, meshing with the rack on the under side of the table, and one pair of gears to drive between the pulley shaft and the diagonal one on which the spiral meshing with the rack is located; this pair of gears in some cases being bevels and in others a second spiral pinion mating with a spur gear. In the table rack the teeth are cut at an angle slightly less than 90 degrees to the line of movement in order to avoid the side thrust which might be expected of such a pinion, and as a result the movement is accomplished without the slightest tendency sidewise.

To demonstrate the improvement in the "spiral geared drive" over the spur geared drive it is only necessary to consider the following facts: On a spiral gear such as used in the "Sellers motion" the points of contact move in flat planes parallel to and extending above and below the pitch line of the rack, and the number of teeth continually engaged is limited only by the design. As generally applied, there are always four teeth engaged, and one can easily conceive of a perfectly smooth motion being the result.

It is obvious that the spur gear cannot accomplish as much. The bearing points of a spur gear and rack are continually changing in position from above the pitch line to below, the contact jumps from one tooth to another, and an exceptional condition exists when two teeth are engaged at the same time. In order to better conditions, it has become customary to make the pitch of the rack as fine as possible in order to get a maximum number of teeth in a bull wheel

of a given diameter; hence the abnormally wide face of some planer racks, and also the explanation of the use of steel for racks and gears in places where the "Sellers motion" would permit making the rack of such pitch and face that cast-iron would be superior in strength and wearing capacity as well as in smoothness of action.

Another scheme used by spur-geared advocates is to make the bull wheel and rack in two sections, staggering the teeth. This makes the irregularities smaller in a given case, provided the gears and racks are accurately set, but at best is only a slight improvement, and, as can be seen in analysis, the first incomplete step in the formation of a spiral gear.

Detailed consideration will show further advantages in the spiral geared drive; viz., the small number of parts, and hence the low inertia, and as a result the decreased power consumption and the promptness of reverse; and the rigid construction obtained at the vital part of the bed.

The Reversing Mechanism.—Two factors have entered into consideration in the development of this part, namely, high-speed return mania and the advance in the art of making high-speed cutting tools.

In speaking of the first factor as a mania, the writer is influenced by the extremes of high speeds attempted by some builders, and the belief, based on practical observation, that even if these high speeds could be obtained in a practical and economical manner, the gain in time would be offset by the difficulty in handling. One of the most important characteristics of machine tool design, and of planer design in particular, is that of sensitive and easy control, and the higher the speed, the more sensitive it should be. As most of the mechanisms designed to furnish extremely high return speed have sacrificed in one way or another the sound conditions of practicability, economy, and control, the end does not justify the means.

If this discussion was of the smaller size planers, say up to 36″ x 36″ capacity (the capacity measured between the housings and from the table or platen to the under side of the cross-rail), the foregoing paragraph would not pertain, but covering, as it does, machines of all sizes up to the largest known, and as those below 36″ x 36″ are so small and the work handled so light as to introduce very few problems in connection with the reversing mechanism, these sizes will not enter into direct consideration.

The development of high-speed cutting steel has had the effect of increasing the cutting speeds and the power required, and along

these lines legitimate and satisfactory results have been accomplished, and a higher percentage of output has been obtained than has been demonstrated by the exponents of high-speed return extremes, and this gain may continue until the cutting speeds have been brought up to the moderate return.

The oldest and simplest reversing mechanism is the "shifting belt," consisting of two belts running in opposite directions, shifted alternately on the driving pulley of the machine. For a long time this form kept pace with modern advances and requirements, and at the present time, if not applied to severe conditions, performs its duties well; but it has limiting features recognized by conservative designers; viz., the maximum width of belt that can be shifted quickly (about 4 inches) and the speed with which the rim of the driving pulley travels on the return (not over 5000 feet per minute). The limits mentioned are exceeded in some designs, steel-rimmed pulleys and other accessories being brought to aid the belt.

An ingenious arrangement passing the speed limit mentioned uses two sets of pulleys and belts, no two belts driving at the same time. One set is used for slow speed cut and return and the other for high speeds in both directions. The reversal is accomplished by the slow-speed belts, and after reversal the high-speed belt is substituted for the slow, and the platen is thus brought up to speed, due to the high-speed belts, in two steps. Theoretically this makes the differential speed changes about the same as in good practice, but with a sufficiently high ratio of belt speed to table speed to give a heavy cut, the rim speed of the cutting pulley on the return must be enormous, if not prohibitive, and the speed of the driving belt at all times so high as to bring centrifugal forces to detract from the pulling power. Some of these planers have returned at a speed of 200 feet per minute, and on light work have been successful. The utility for general or heavy work has not been demonstrated.

Another design, based on shifting belts, is used by an English builder. In combination with the belts, a pair of what might be termed fly-wheel clutches are used at the moment of reverse. The fly-wheels act as loose pulleys for the shifting belts, and as the belts are never shifted entirely off them, are continually stored with energy. When a belt is shifted to the driving pulley, the same shifting mechanism engages through the clutch the fly-wheel with it, and the energy stored therein assists the belt to reverse. In connection with this

device, the rack under the table drives through springs, thereby furnishing a cushion for the reversal.

It is likely in the above conditions that if the springs do their share of the work—and they must do considerable—the variation of power consumed in the cuts must be small in order to have a uniform movement of the table, and so a smooth cut, and it also seems doubtful that this drive will stand up for a long time on short strokes, instead of that it will reverse with a great degree of accuracy, or lend itself to satisfactory hand operation.

Still another high-speed return device, using shifting belts, also English, adds spring buffers stationary in the bed. Movable stops on the table engage these buffers at the time the usual table stops are shifting the belts. What happens if the table is reversed by hand, between the limits of the stops, not utilizing the springs to assist the belts, is not on record.

Before leaving shifting belts we must mention the application of two sets of shifting belts to one machine, two belts acting simultaneously. This permits the same return and cutting speeds as are used on the single set, while furnishing nearly double the power. The additional work required to shift the extra set of belts may be overlooked, but the power consumed at the moment of reverse will be practically double that used on a single set of pulleys, the inertia of the table up to the permissible speeds with shifting belts being practically negligible.

Departure from Shifting Belts.—The first design to be considered is advanced in an attempt to pass the limits of power, not the limits of speed, of a shifting belt drive. Two belts running in opposite directions and hanging vertically embrace loosely two pulleys fast to the pulley shaft. Idler pulleys, actuated either by hand or automatically, act as belt-tighteners and cause either one or the other of the belts to drive as desired. A modification of this scheme uses the two oppositely running loose belts, but in place of the extra tighteners, hangs the countershaft pulleys on a rocking frame, one on each side of the center, and thus combines counter and belt-tightener. These last two schemes, simple though they seem, have some very undesirable features; briefly, the inclination of the belts to drag, the inertia incidental to the wide-face pulleys (high belt tensions could not be used), and the uncertainty of reverse, not to mention the wear and tear on the belts.

Clutch Reversing Mechanisms.—Various types of clutches and

numerous agents have been tried in the development along this line, but with a very small measure of success until the advent of the pneumatic clutch. The mechanically operated clutches, the first type tried out on planers, were successful as long as adjustment was continually looked after. On account of the large ratio required between the operating movement and the clutch movement to develop high power, the wear of the clutch surfaces, as well as the changes in conditions, affected the power developed. This, coupled to the cost of the mechanism required to produce an easy and prompt reversal and the skill required to make adjustments, led to the withdrawal from the market.

The magnetic clutch has not been brought to the degree of perfection required on a planer. The uncertainty of release has proved the most serious objection, and as this is very important, is sufficient to bar its use.

The pneumatic clutch, when properly designed and constructed, possesses all the necessary characteristics—elasticity, promptness, power, and easy control. It is true that some clutches built along the lines of a Weston clutch (a number of friction discs, alternate ones keyed to the driving and the driven member) have given considerable trouble, but it can be safely said that the trouble has been due to one or two causes, or perhaps both—a construction in which prompt release is not assured (a cone clutch overcomes this feature) and the direct connection (geared) to a motor. A belt between the motor and the clutches is almost essential; it relieves the clutches of a considerable amount of slipping and the motor uses less current at the moment of reverse.

Planers can be designed with a pneumatic clutch drive to take a cut at any speed up to the speed of the return, the return speeds can be made as high as is thought practical, the cutting power as great as desired, and it is possible to operate on shorter strokes and with greater ease of manipulation than with any other known device.

The most practical machines of to-day are designed to run at or about the following speeds:

36 inches × 36 inches	up to	54″ × 54″	 100	ft. per min. return
60 " × 60 "	"	72″ × 72″	 90	" " " "
84 " × 84 "	"	168″ × 168″	 80	" " " "

On shifting belt machines these speeds are approximately 20 per cent. lower.

There are several requirements of a modern planer that lie outside

the drive and reversing mechanism. In considering them briefly it may be well to start with the one closest to, in fact almost part of, the premier considerations, namely, variable cutting speed devices.

As met in some designs, this element comprises mechanisms containing high-speed gears or short center belts, both objectionable, especially where high powers are concerned. These devices permit of quick changes of speeds, but the first-mentioned introduces superfluous running parts, and the latter, to say the least, is inefficient.

The simplest and most effective method of varying the cutting speeds is through change-gears conveniently located and easily handled. It may take several minutes to make a change, but the simplicity and efficiency more than compensate for this, unless the work be exceptional, and requires continuous changing of speeds. The modern practice is to keep a machine on one class of work, and the times that the variable speed feature is of use are few and far between.

An electrical control for varying the cutting speed is on the market. This has the objection of slowing down and speeding up all of the constantly running parts at each end of the stroke, the reverse always taking place on the slow speed and strongest field of the motor.

There has been some exploitation of a planer that starts into the cutting stroke at a very low speed, and after the tool has entered the work accelerates to an extremely high one. This might be of value on very small machines, where the pieces handled are too light to permit of heavy cuts, but on the moderate size planer, say, from 36 inches up, the general work permits the use of the maximum horsepower that can be delivered, on the moderate-speed cuts, and as it is more economical to take heavy cuts at slow speeds than vice versa, the scheme seems of questionable value under general conditions, at the present time.

Let us now consider the two forms of feed motion used to-day: One form is driven directly from the main drive and is subjected to the same changes in speed as the table—slow on the cut and fast on the return. This type requires a longer stroke of the platen for a given piece of work than does the other, which is independently driven, at the maximum permissible speed, and may be started in operation just at the end of the stroke, feeding the tool *during* the reversal. In the first-mentioned design *all* of the feeding must take place *after* the platen has reversed.

Next in order may be considered the crosshead construction, which

varies in different designs from a traverse bar, reinforced by a curved back, strong to resist direct strains, but weak at the points of greatest torsional ones, to the same traverse bar reinforced by a back of continuous cross-section, reaching from upright to upright, which, being clamped to the uprights at the extreme back corners, as well as at the face of the housings, presents a maximum resistance to both direct and torsional forces, and ties the uprights firmly together at the lowest possible point, giving added strength and stiffness to said uprights to resist the strains due to tools operating in the side-heads.

In concluding, the writer does not wish to be understood as condemning any of the schemes criticized as being of no value. They are, generally speaking, ingenious, and have value along certain lines and up to a certain point of usefulness, and with modifications may be worked out to great advantage, or, if confined to particular lines of work, may prove satisfactory in their present form; but for general practice the lines followed by conservative builders, of keeping well within the limits of economy as regards manufacturing possibilities, not sacrificing one essential point in order to carry another to an extreme, and not introducing such features as mere "talking points," produce the highest class machines.

The addition of automatic labor-and-time-saving devices for the purpose of furnishing "talking points" for selling and advertising, has made appeals to a certain class of buyers; but if the time comes when one who knows what is needed buys, and when one who knows what he has, sells, and the buying and selling settle to a point where commercial becomes practical value, then the machines (and this applies to more than planing machines) having numerous exceptional features of doubtful practical value will be a drug on the market, and the aim will be toward simplicity and efficiency.

PAPER No. 1072.

INTERURBAN ELECTRIC RAILWAYS.

BENJ. FRANKLIN.
(Active Member.)

Read April 17, 1909.

THERE are many problems involved in electric railway location and construction which are not touched upon in this article, partly because a busy professional life has prevented investigation, and partly because they seem to belong within the province of the electrical engineer or the operating department. There are points, however, involved in the experience of the last few years which indicate so great a development along engineering lines that with a view to inviting discussion this article is presented.

The evolution of electric railway engineering has been so rapid that it seems incredible that a little more than ten years ago it was an almost universal practice to construct lines along public highways, quite disregarding steep gradients and sharp curves. While in steam railway location anything heavier than a 1 per cent. grade or sharper than a 5-degree curve would be given gravest consideration, even engineers of ripe experience and sound judgment did not hesitate to construct an electric railway on a 33 feet wide country road which would involve grades as high as 8 and 10 per cent. and curves with 50 to 70 feet radii.

We may venture the opinion that in the earlier days very few foresaw the magnificent future of the interurban electric railway, but looked upon the first lines radiating from or connecting centers of population as being only an improvement on the horse-car lines in both speed and economy of operation. The burden of responsibility for not reaching earlier a higher development in location really rests upon the legislator, by reason of imperfect and deficient railroad laws.

In some States, particularly in the west and south, the law made no distinction between a steam and an electric railway, while in others, to quote a legal authority, electric railways were "absolutely lawless," in that there was neither legislative act nor decision of court to give them a status. For example, in our own State the power of eminent domain and the right to carry freight were granted to electric railways only at the

session of the legislature of 1907, and further legislation will be necessary to remove some obstacles from the path of their highest development. When, therefore, the engineer entered upon his location with the knowledge that his right of way could only be acquired by either gift or purchase, his problem was a difficult one. Under present conditions in most States, in the location of a high-speed interurban railway, the engineer views his problem almost precisely as if it were for a steam road, endeavoring to obtain such an alinement as will give easy grades and curves; bearing in mind that high speed, safety, and minimum cost of operation and maintenance are essential. In an entirely new country or one that is thinly settled his work is simplified, but in thickly populated districts the problem of location is complicated by the existence of one or more lines of steam railways, occupying the best natural routes, and in many cases so preëmpting controlling points that heavy and expensive work is entailed.

Owing, however, to the use of the multiple unit system of electric control and operation, the engineer has considerable latitude in the matter of grades, and as the use of a 2 per cent. or 2½ per cent. gradient is good practice, and fully warranted on lines intended for passenger and light freight traffic, he has some advantages which offset those acquired by being first in the field.

In the present stage of electric railway development it can be stated as a general proposition that interurban railways cannot compete with steam railways as far as time is concerned, not because a higher rate of speed cannot be attained, but because a greater accessibility to the traveling public is demanded. Promoted and built essentially for passenger traffic, an electric railway, in order to compete with the steam railway, must be more easily reached, its service must be more frequent, and the fare lower. The interurban road must carry its passengers to or near the principal railroad stations, hotels, theatres, and other places of resort, and must make connections with local street railways. Even if one or both urban terminal roads are subways or elevated, the road must pass through the principal streets of the towns and cities along its route, making numerous stops, and necessitating in part surface highway construction, involving loss of time. Therefore, while the public demands high speed and the engineer carefully weighs every problem in his effort to attain it, yet he must bear in mind that convenience and accessibility commonly net the passenger a greater saving of time than he can obtain by the quicker steam route.

It is true that all of these conditions can be attained by the con-

struction of the road on an "individual right of way," that is, a private right of way with no grade crossings; but this makes the cost of construction so excessive that competition with steam railways in suburban territory in the matter of fares is out of the question. The author's firm, within a few months, made a survey of a short road, the estimated cost of which for a double track was about $115,000 per mile, exclusive of equipment and power plant, and only the principal grade crossings were avoided. To have obtained a strictly individual right of way might have resulted in a slight saving in time and risk, but would have made the cost so burdensome that the proposition could not have been considered.

In thinly settled districts where it is desired to have rapid transit between the termini, the steam railroad schedule can be met successfully. The author a few years ago located the Iowa and Illinois Electric Railway, between Clinton and Davenport, Iowa. In avoiding grade crossings and obtaining the best alinement no attention was paid to the cost of the right of way and no important detours were made to intermediate centers of population, and as a result the location obtained permitted a high rate of speed. The road is 40 miles in length, passing through two important intermediate towns; the fastest time made, including stops, is sixty-seven minutes. An express train on the Chicago, Burlington and Quincy Railroad, a competing steam line, makes the trip in fifty-nine minutes, the next best time being sixty-eight minutes. The best time made by the Chicago, Milwaukee and St. Paul Railroad, another competing steam line, is seventy-five minutes.

There is also another factor which ought to influence the engineer in making his location, and that is the ease and economy with which some steam roads, in possible competition, can electrify their systems, especially where the lines are comparatively short and heavy freight is not handled. Such a change would in many cases reduce to a junk heap expensive individualized electric railways. Granting, therefore, in order to give convenience and accessibility to the centers of population along its route, that a partial street or highway location is necessary, the engineer should endeavor to limit such location to the shortest possible distance, and seek along a private right of way a location in accordance with the topography of the country, and not the lines of travel already in existence.

The experienced engineer knows this fully, but in many cases the apparent economy of obtaining a location on a highway at no cost for the land offers so strong a lure to the promoter and capitalist that

charters for roads of that character are still applied for. The objections to such a location can be briefly stated. In this country highways are generally constructed without regard to the topography of the country they traverse, usually following township and farm lines, resulting in heavy grades and sharp angles. Instances of such interurban roads with 8 and 10 per cent. grades and 50 feet radius curves are not uncommon. Again, as the track grades have to conform to the highway grades, and many of the latter simply follow nature, a uniform gradient is rarely possible. Except in thinly settled communities high speed cannot be attained. Each farm-yard and dwelling entrance becomes a grade crossing, necessitating a speed always under control for sudden emergencies; and as entrance to the highway cannot be denied from any private property, the development of a community increases the number of grade crossings. The cost of roadway maintenance is at a maximum. The track-bed is difficult to drain, usually receiving the drainage from the highway, so that the ballast soon becomes filled with dirt, and the life of the ties is shortened. With a compact highway on one side of the track, and an open ditch on the other, frost action necessitates frequent realinement and resurfacing; and provision must be made for the highway drainage as well as that which belongs to the track bed. The question of future exactions of the governing bodies controlling the highways must be considered, and also the very important item of damages. On a highway location there are elements of danger which never appear on a line having its own right of way; such as damages resulting from collision with teams and injury to pedestrians who at times must cross the tracks. These aggregate a heavy annual expenditure, which in almost every case exceeds the interest on what would have been the cost of a private right of way when the line was originally projected.

When private right of way can be obtained without restrictions, there is no reason why the standard cross-sections of the leading steam railroads should not be employed. The principal requisites are the insuring of perfect drainage through proper slope of road-bed, form of ditch, and side slopes; and if overhead construction is used, sufficient clearance for the poles. The standard of the Pennsylvania Railroad, adopted in 1906, gives most excellent results, and can be used for either overhead or third rail construction. If greater economy in grading is desired, the track centers can be narrowed, although in our judgment the "dummy" ought not to be less than six feet in width. The berm outside the toe of the ballast can also frequently be narrowed, as the

rolling stock is lighter and the grades of an electric railway usually heavier. Before electric railways were accorded the right of eminent domain it was often difficult to obtain rights of way of sufficient width, and standard engineering principles of drainage and slope were frequently modified for economy in space. Where the tracks were laid on the bed of a highway, the problems of pole clearance, of space for vehicle travel, of highway and track drainage, taxed the ingenuity and resource-

FIG. 1.—Section of narrow right of way necessitating paved gutters.

fulness of the engineer. In paved streets where wooden ties are used the construction should be of such a character that the ties can be replaced without disturbing their foundations. Where highways are intersected and inlets cannot be built at the intersections, the problem becomes a complicated one, as the subgrade of the road-bed is frequently below the highway ditch or gutter. In running through swampy land or quicksand, where it is impossible to construct deep, wide ditches, or the right of way is to be paved, drain tile can be used to very

great advantage. Figs. 2 to 7 indicate various ways in which these problems have been met.

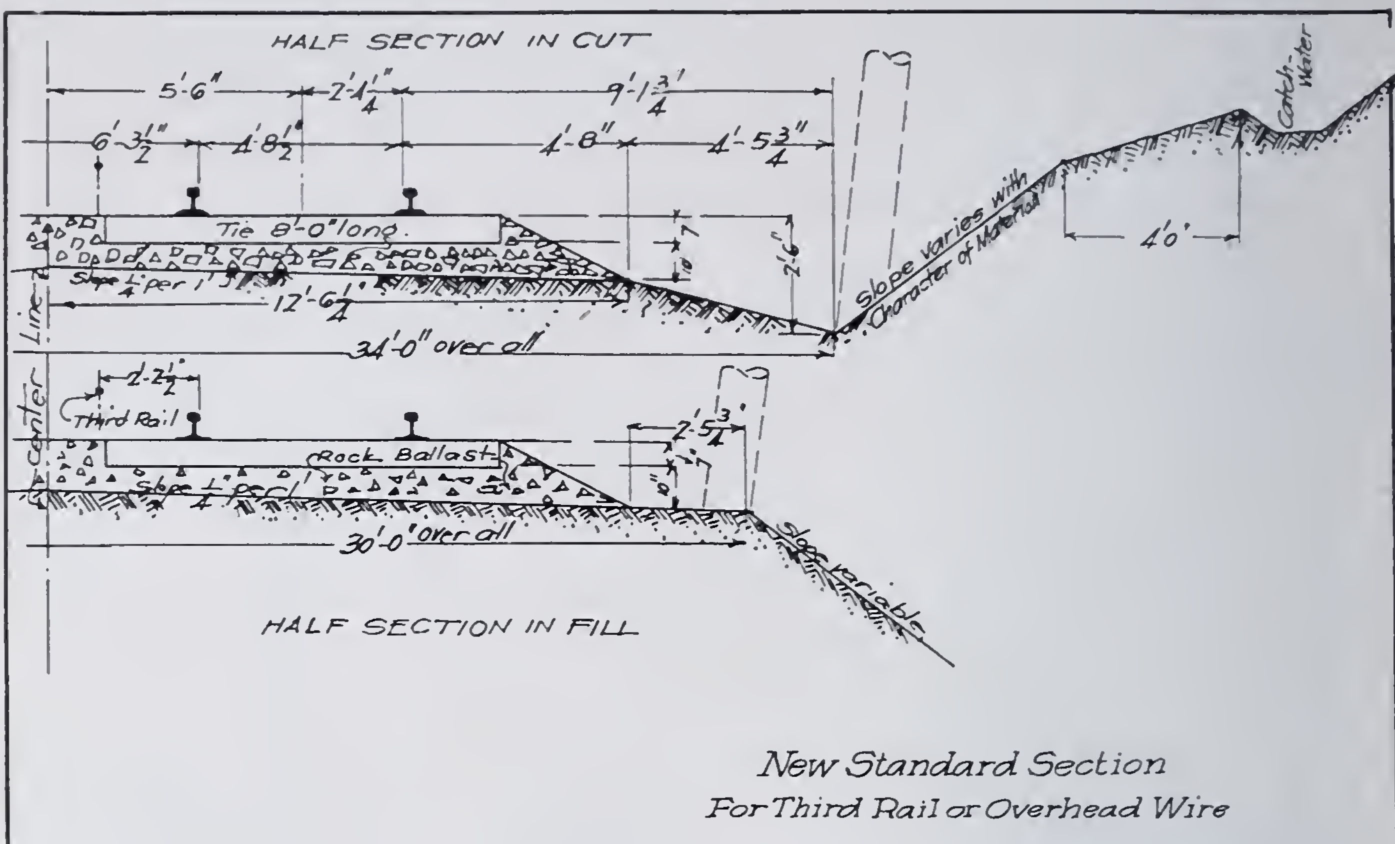

Fig. 2.

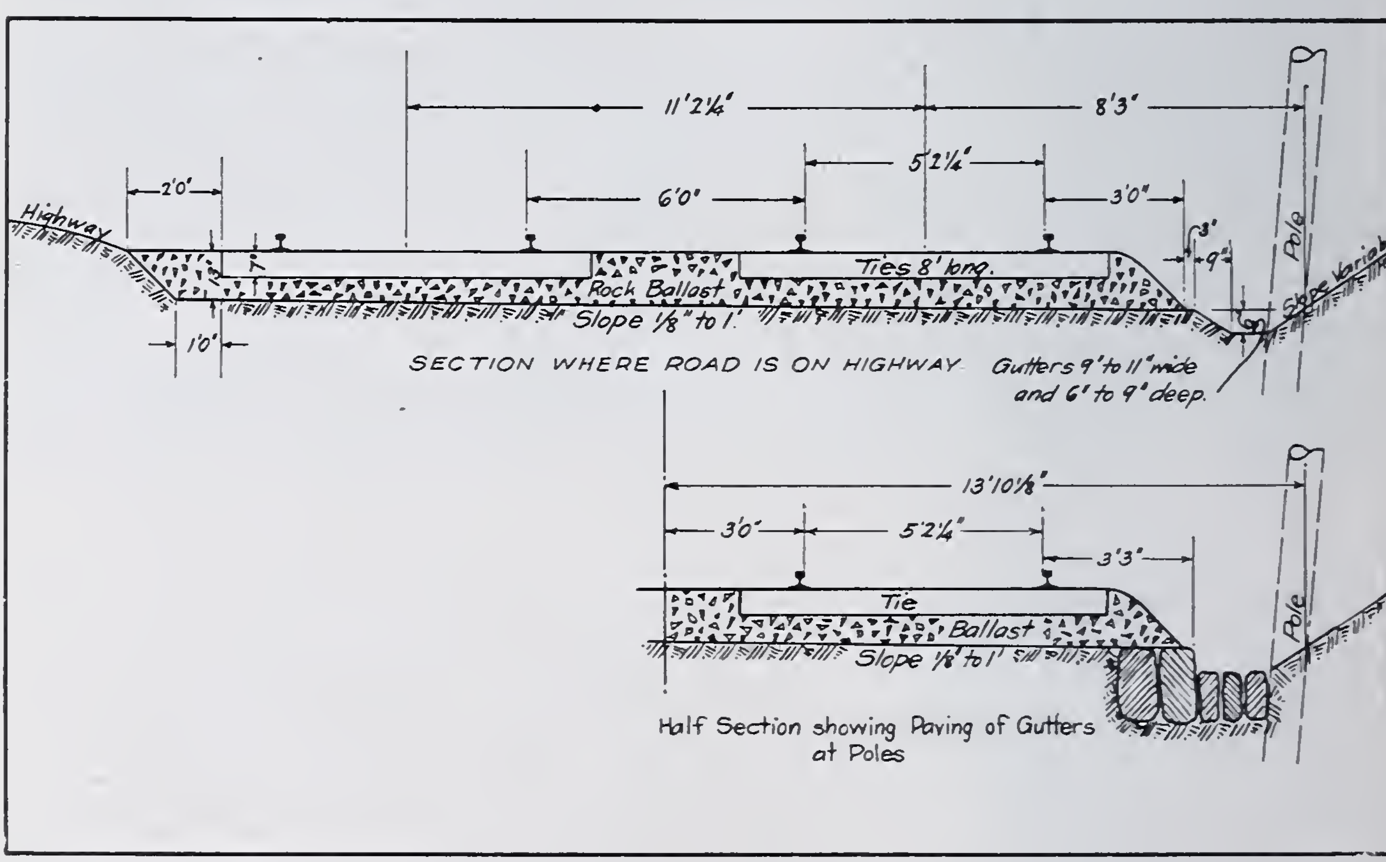

Fig. 3.

Aside from the track-work, there is but one point of importance in the construction of the road-bed to be emphasized here, and that is the

rolling of the subgrade with a steam-roller, after the grading has been completed. This applies to the cuts as well as the embankments. We advocate the use of a steam-roller not because we believe that it appreciably solidifies the embankments, but because by compacting the surface of the road-bed a more economical use of the ballast can be obtained. In the finishing of a road-bed, whether it be in cut or fill the subgrade to a depth of 1 inch or more is soft and loose. If on this is spread the ballast to its full depth, dust and grit from stone, and loam

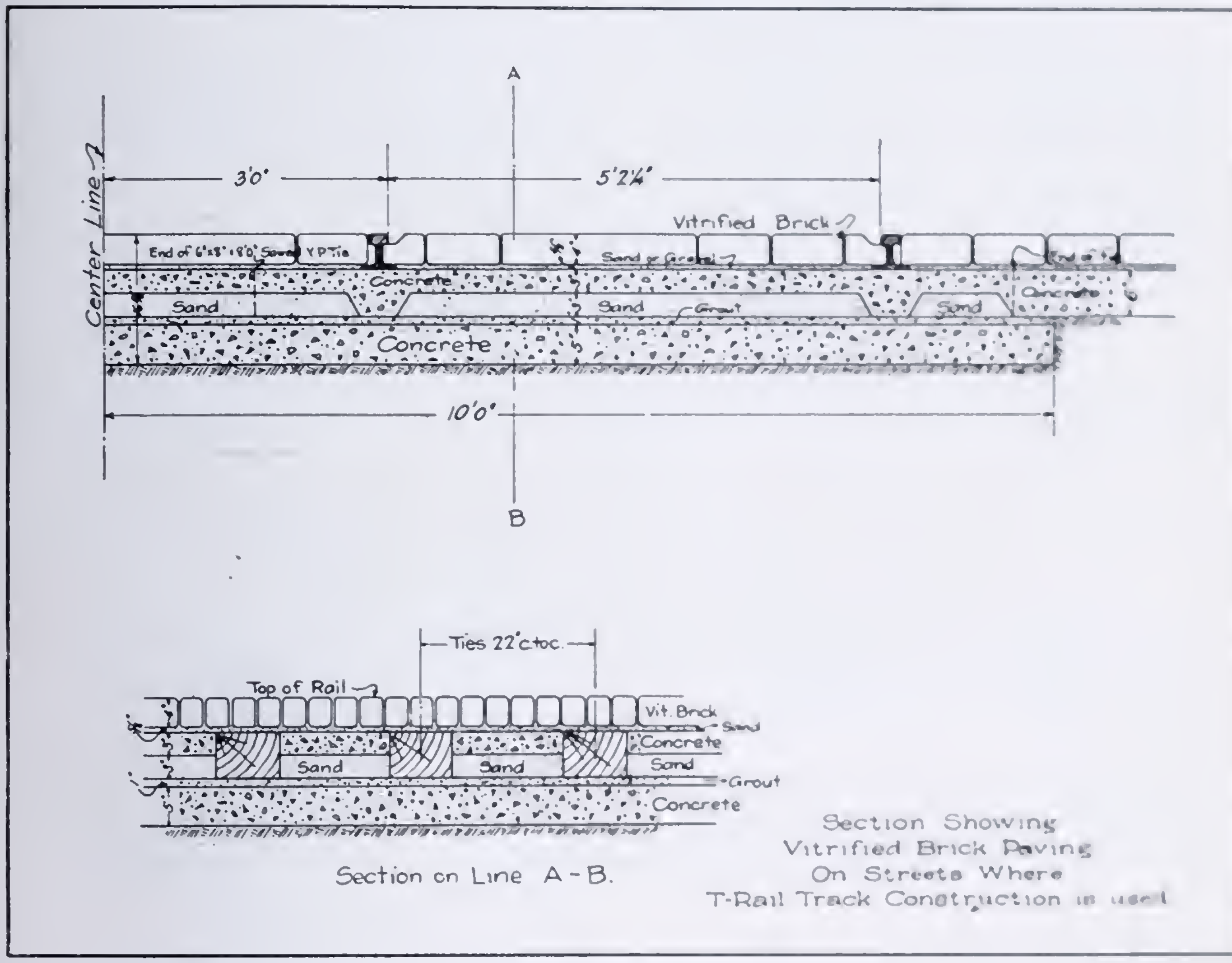

FIG. 4.

and clay from gravel are washed down by rains into the loose soil, with the result that the bottom stratum to a considerable depth is a mixture of soil, ballast, and dust, almost impervious to water and practically useless as ballast. When the soil is stiff, this condition is not so apt to occur in cuts; otherwise the results are exactly the same as rolling the subgrade for a macadam road. The crowning is secured, the ballast is laid more uniformly, and is but slightly mixed with the soil, and where teams are employed the danger of rutting is lessened. We believe also that new embankments, when so treated, preserve their contour longer.

as their settlement seems to be more uniform. Taking $10 per day as

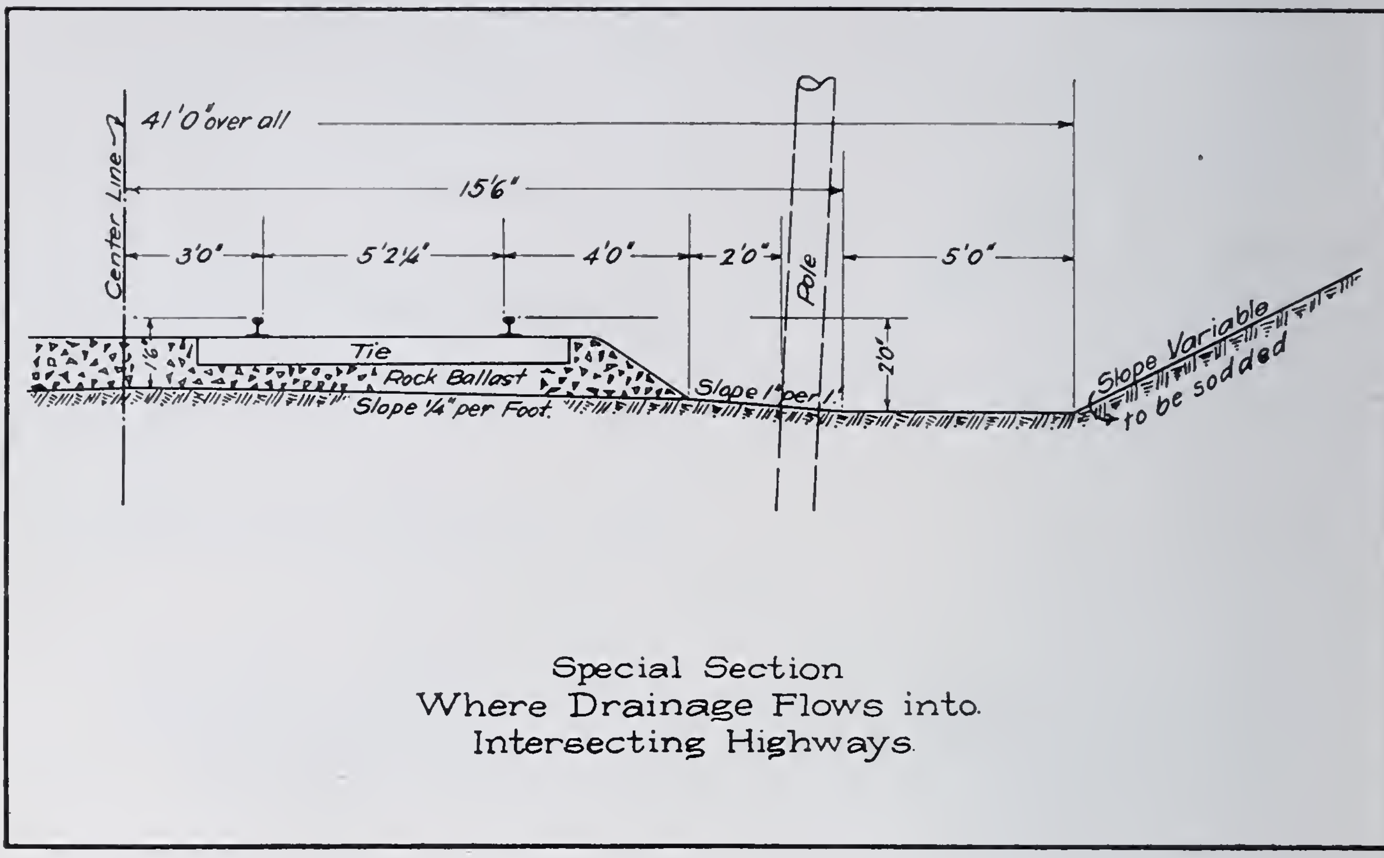

FIG. 5.

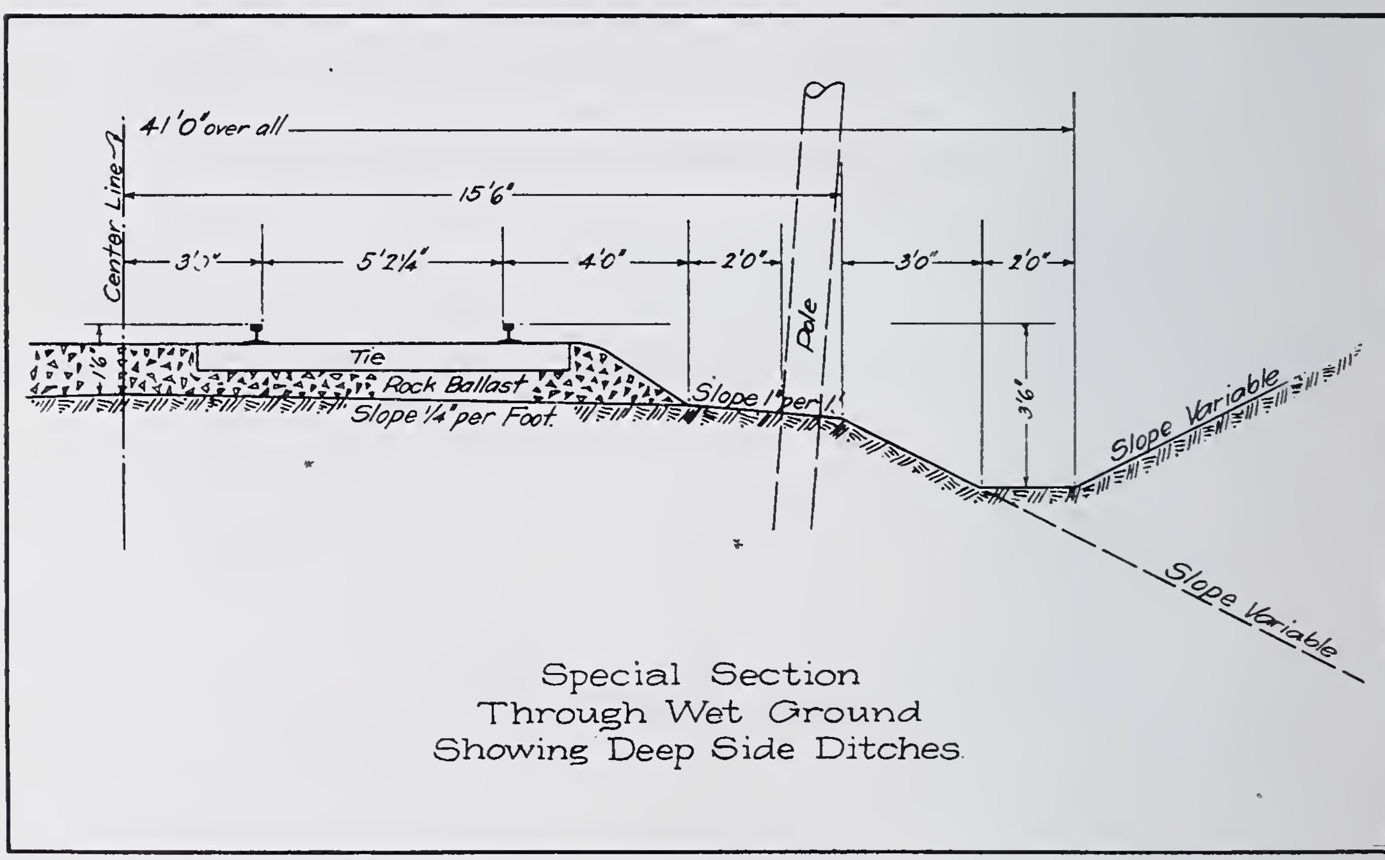

FIG. 6.

the rental of a steam-roller, independent of fuel and water, the cost of rolling a double-track road-bed ought not to exceed $50 per mile.

A further economy may be effected by the use of the steam-roller on

rock ballast before the ties are laid, for by rolling the ballast is firmly

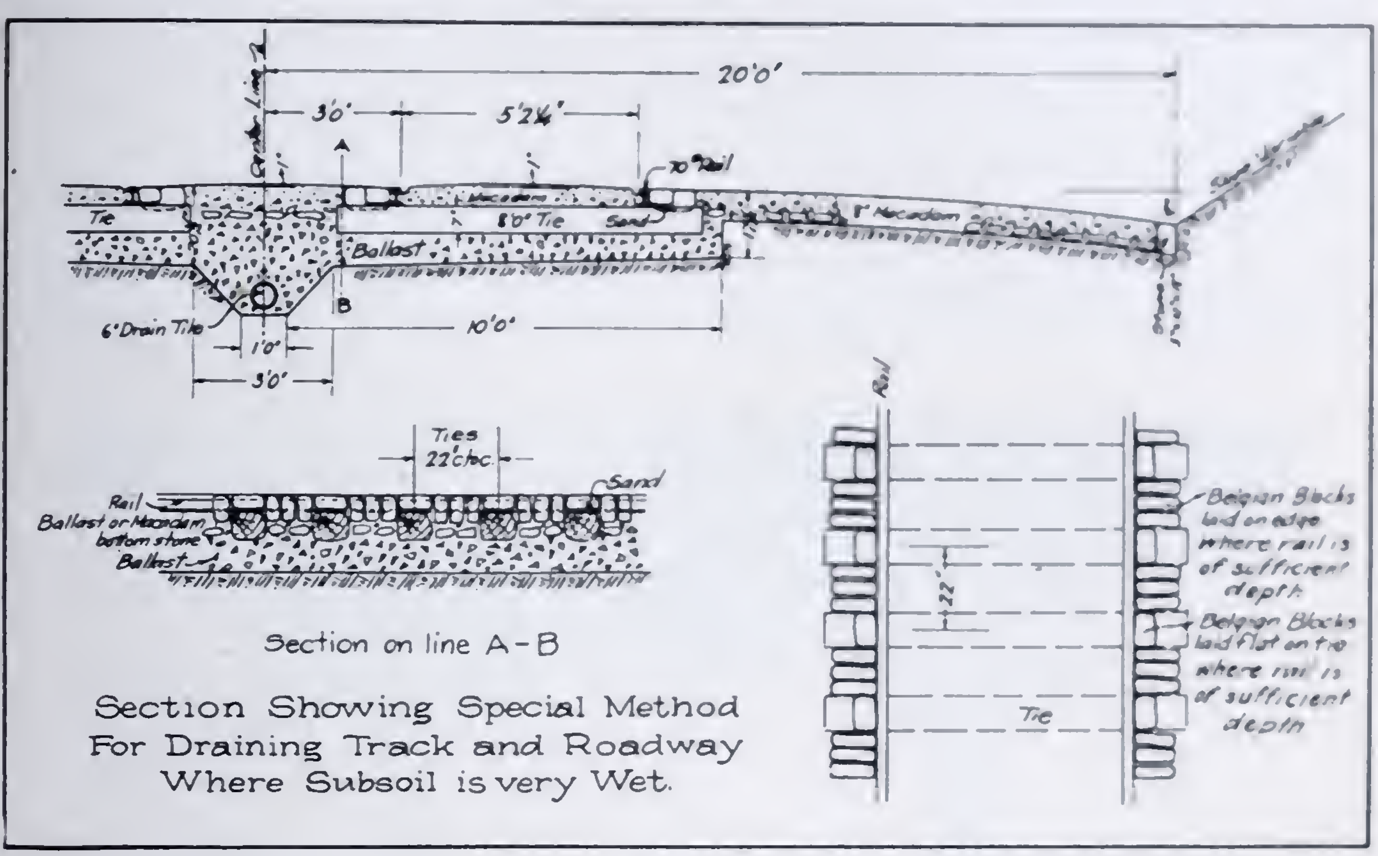

FIG. 7.

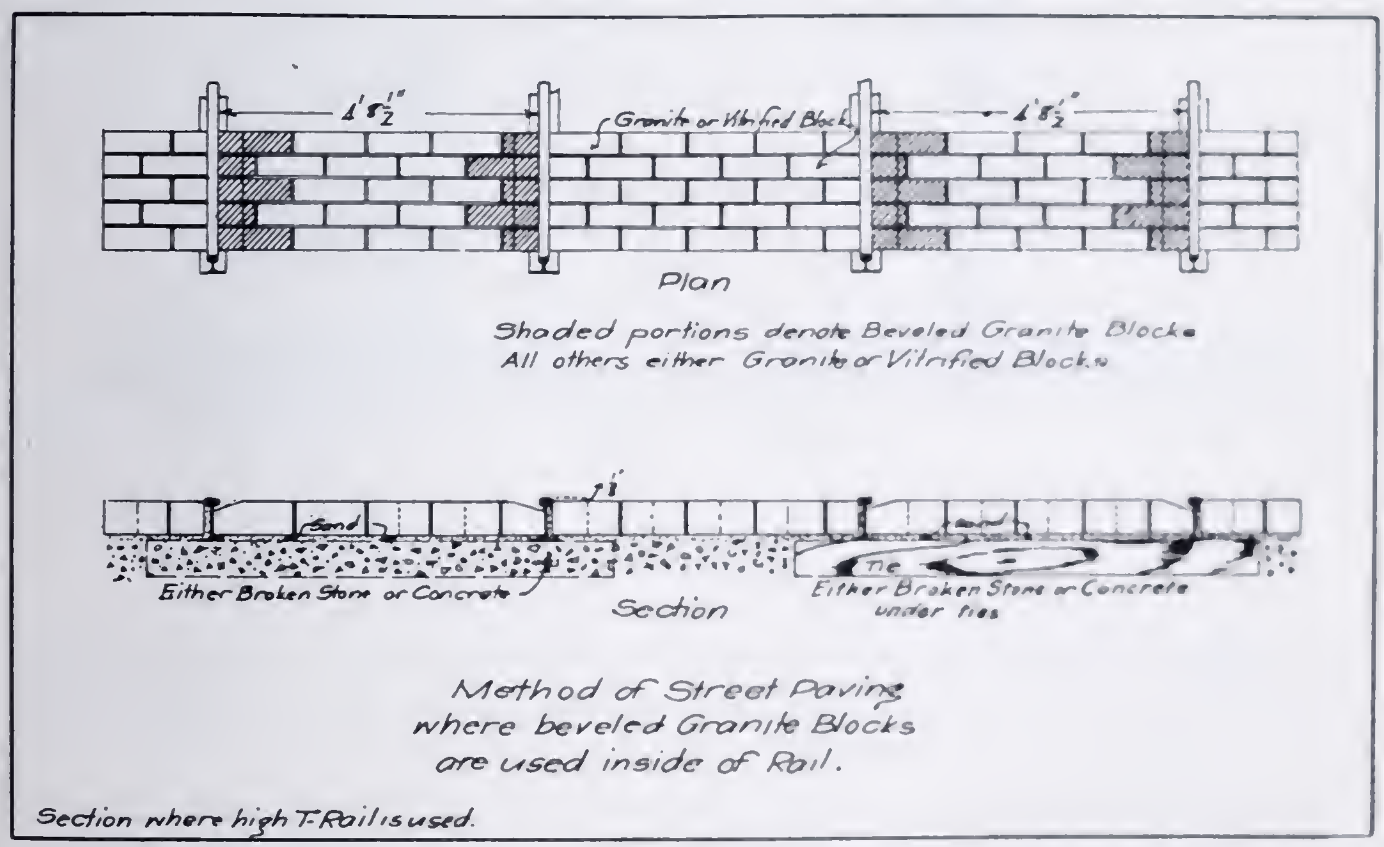

FIG. 8.

compacted, requiring less tamping; and the rail surface secured is better and more easily maintained.

The weight and length of the rail to be used have been matters of

considerable discussion among electric railway engineers, opinions as to the best practice varying from 70 lb. to 80 lb. A. S. C. E. section. It is true that a heavy rail possesses some advantages in alinement and surface and in wear at the joints; and the question to be determined is superiority of maintenance on the one hand, and consideration of first cost on the other. The principal factors which determine the weight of the rail, assuming that the ties are properly spaced and the track-work well ballasted, are the weight of the cars, the rate of speed, and the

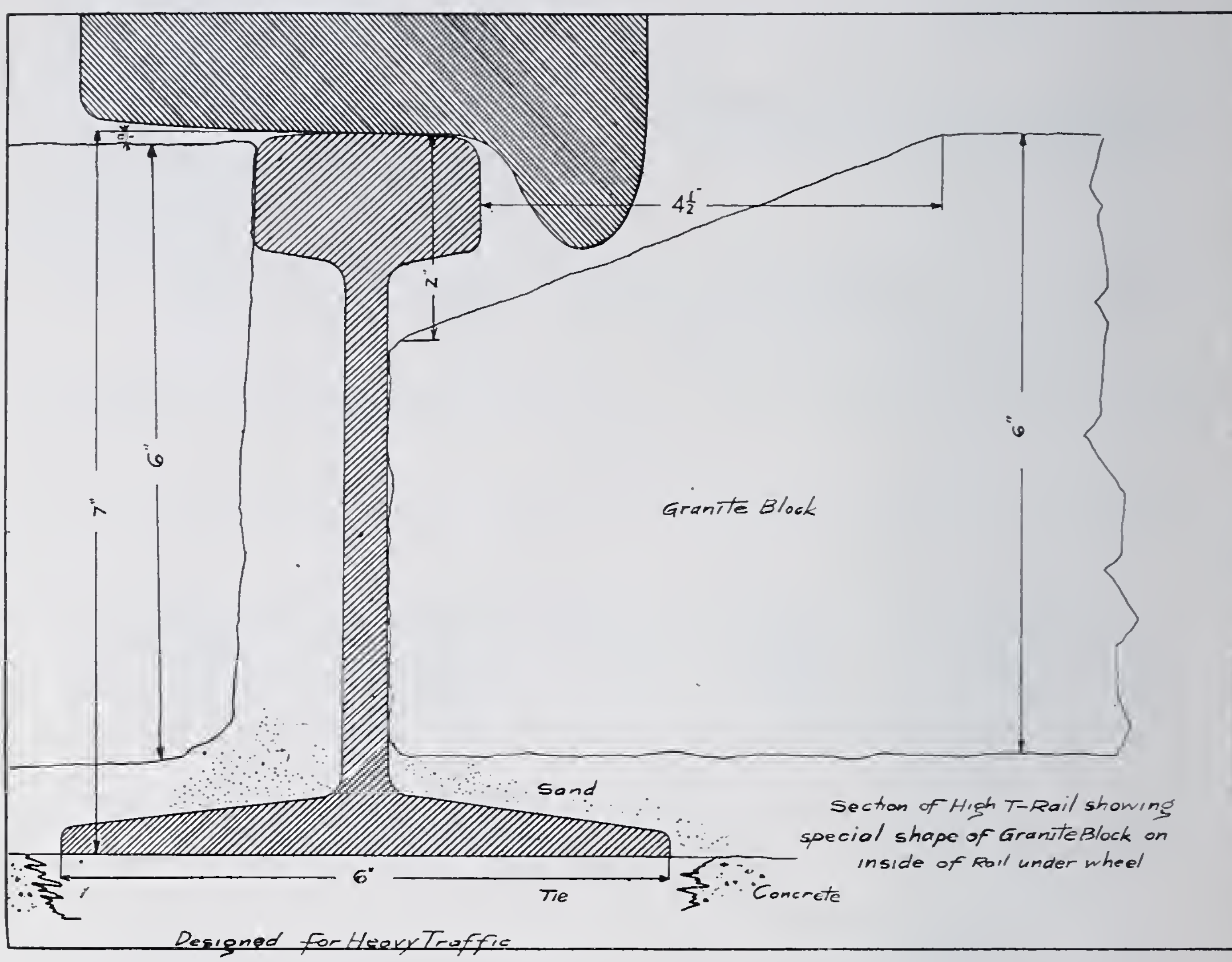

Fig. 9.

amount of traffic. The heaviest cars manufactured by the J. G. Brill Company, of Philadelphia, were for a western road and weighed about 38 tons complete, with electrical and air-brake equipment. These cars had a seating capacity of sixty-six, giving a possible maximum live and dead load combined, when crowded with passengers, of not over 45 tons, or a fraction more than 11 tons per axle. The heaviest locomotive on a steam railway has a load of over twice this amount per axle, and, in addition, delivers a hammer blow, which soon affects the surface of a track if any deterioration is allowed to occur.

There are steam railroads which bear heavy traffic using a 60 lb. rail with only gravel or dirt ballast; and while this is not first-class, since it is possible, it does not seem logical to use more than a 70 lb. rail for one-half the load. Moreover, on a steam railway with its mixed traffic there is a possible racking of the road-bed by defective wheels and trucks of freight cars which the passenger service of the other renders unlikely. Consequently if 2640 ties per mile, rightly spaced at the joints, are used and laid on 5 inches of crushed stone, with ordinary

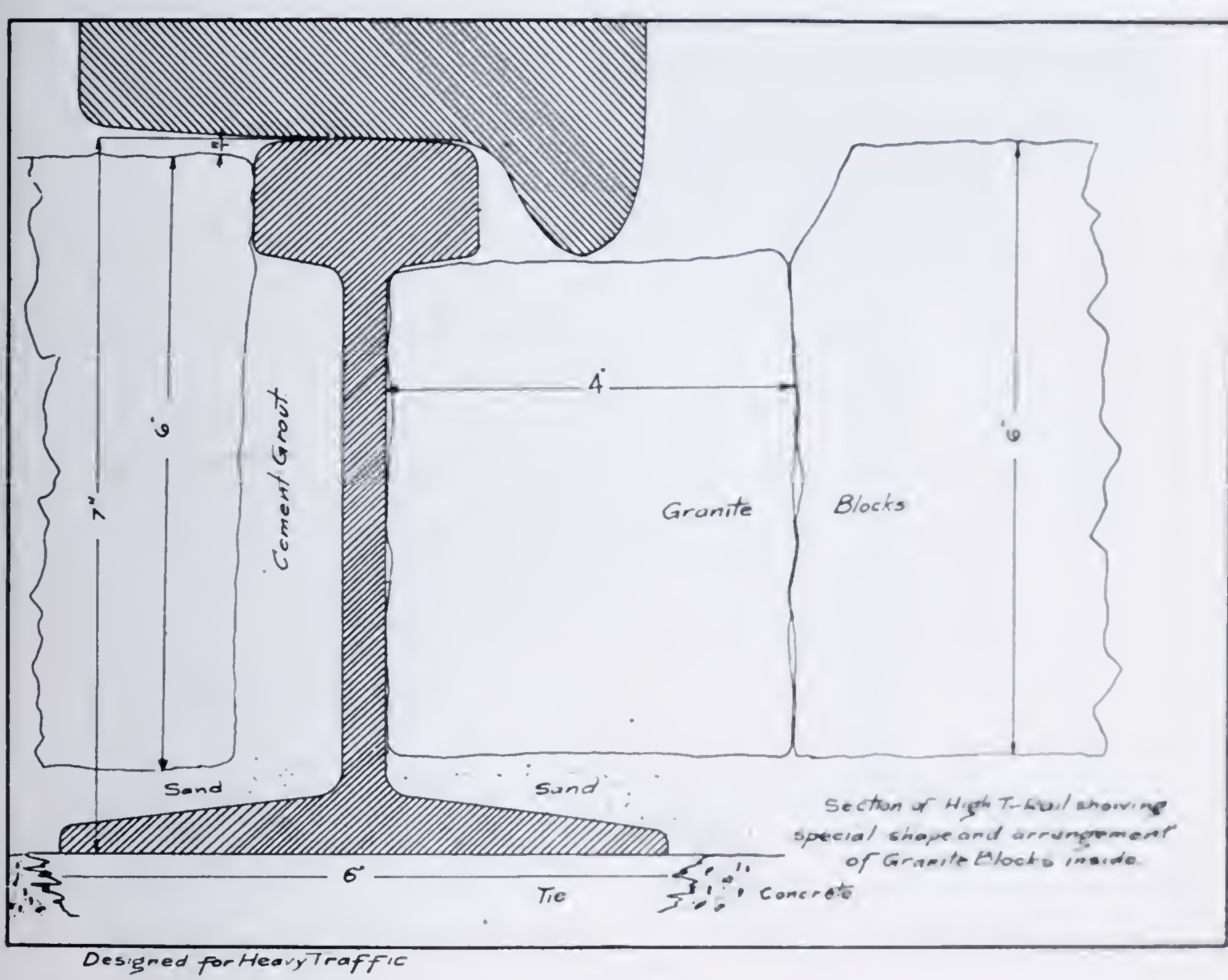

Fig. 10.

track supervision a 45-ton car running at a maximum speed should not require more than a 70 lb. rail.

Induced by an undoubted saving in bonds and splice bars, some engineers advocate the use of rails 60 feet long. Where the conditions are such that welded joints are advisable, or where the rails are well covered with ballast or protected by street paving, it is possible that a long rail may be used and maintained with economy. Under ordinary conditions the saving is offset by the increased cost and difficulty of track maintenance; especially as the ends of the rail are liable to

excessive pounding owing to the wide spacing for temperature changes made necessary by their length.

One of the most important features of electric railway construction, and one which is still a subject of controversy between electric and municipal engineers, is the type of rail best suited for paved streets and the character of the paving best adapted to the type. On paved streets there are at present in use the following types of rails: The step or girder rail, the grooved rail, the "Trilby" and the "T" rail.

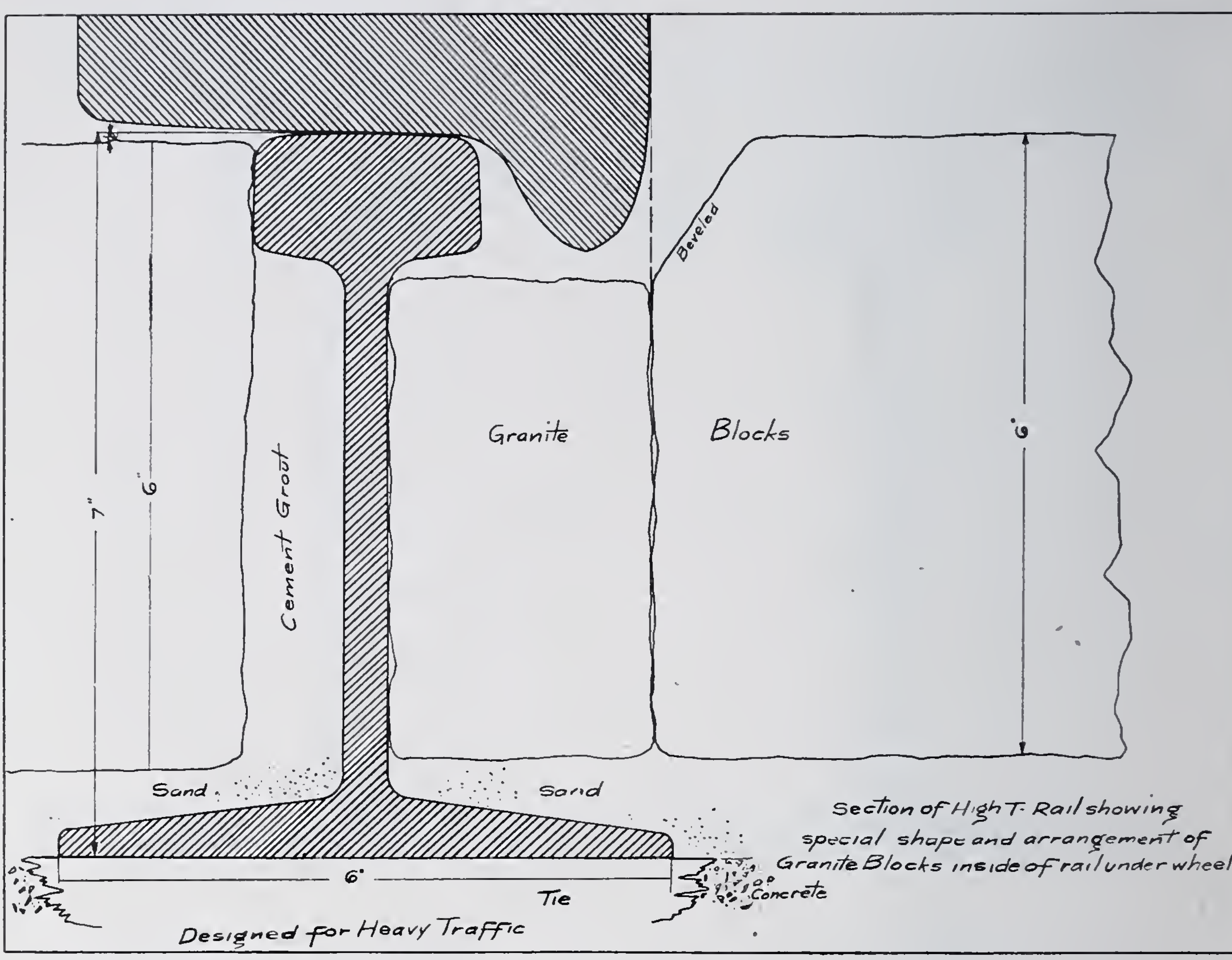

Fig. 11.

For the old horse-car, which was light and slow, the rail problem was an easy one, the girder rail being the almost universal type. The introduction of electricity as a motive power, with the heavier car and greater speed, soon developed unsuspected and important defects. Also the extension of the city electric road into an interurban railway necessitated radical changes in both track-work and paving. The electric railway engineer has in view mainly speed, consumption of power, safety, and endurance. The municipal engineer demands consideration for the vehicles that in crowded city thoroughfares must use the tracks, and durability of the pavement laid adjacent to the rails.

On interurban roads where high speed is desired, safety requires the use of wheels of the Master Car Builders' Standard, which have a tread 3⅜ inches wide, with a flange 1¼ inches deep. Wear will eventually add about ¼ inch to the flange depth, so that with any type of rail on which they are used these conditions must be met.

The car traveling between two large centers of population passes through the paved streets of intervening towns, and frequently into the centers of the terminal cities. Therefore the track-work constructed must not only accommodate the type of wheel used, but must accord with a first-class paved street surface.

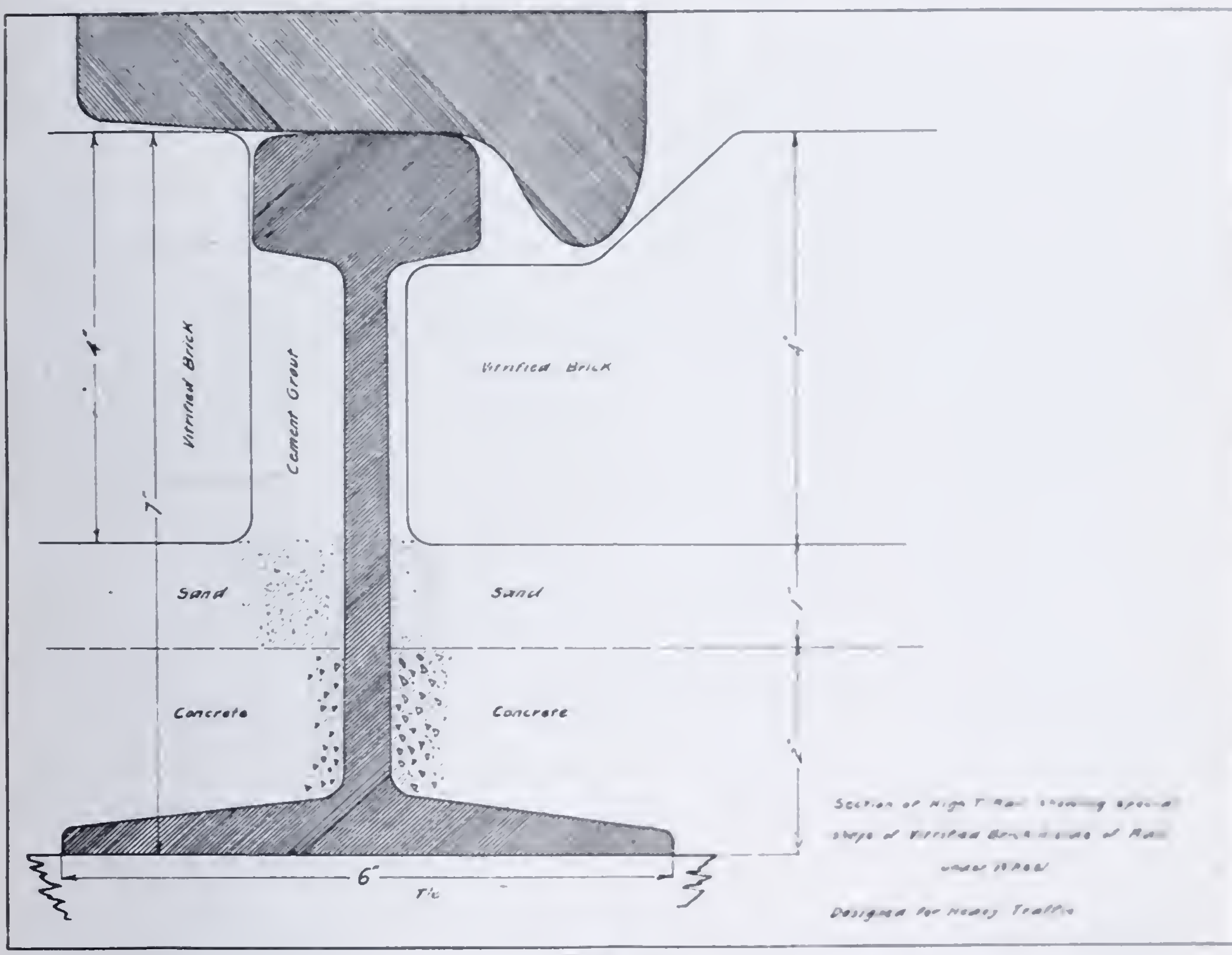

Fig. 12.

But a very small percentage of the girder and grooved rails manufactured will accommodate the M. C. B. flange, and even against those there are serious objections advanced. Personally, we would eliminate the girder rail altogether, as it is not strictly center-bearing, and its projecting tram offers a driveway for vehicles, so that the loading in either case is eccentric, making it difficult to hold the track to gage and causing the joints to rapidly pound down. Also a most serious objection is raised by the owners and drivers of vehicles. The flange way is

vertical, so that in turning out from the track the wagon wheels are strained and often badly injured, a difficulty which is almost insurmountable when the standard wheel flange is accommodated.

The grooved rail, although an improvement, in that it protects the paving and prevents vehicles from "tracking," has its own defects. In cold weather when the service is infrequent the groove may become clogged with ice, snow, and frozen dirt, retarding operation of the cars, and, as the wheels may slide on their flanges, interfere with proper braking. In ordinary weather, unless the service is constant, it is difficult to keep the groove clean, and even a small obstruction may be sufficient to derail a car going at a moderate rate of speed. It is also claimed that in wet weather the water in the grooves being thrown up by the wheels soaks the armatures and causes them to burn out. The claim of excessive wear on wheel flanges and increased power consumption is one open to discussion.

The "Trilby" rail is a modified form of the grooved rail, the flange forming the groove being prolonged nearly horizontally into a lip; and overcomes many of the objections urged against the original. In the Trilby section the bearing of the wheels is squarely over the web and the center of the base, the groove is practically self-cleaning, and excessive wear on the wheels is avoided. Teamsters generally approve of it, for when the vehicle does get into the groove, the slope makes it easy to leave, and wheel wear is saved as well as track. Section No. 402, manufactured by the Lorain Steel Company, is modeled to accommodate the standard wheel flange. This type of rail, even under the severest tests of heavy street traffic, is found to protect the paving and give satisfactory results.

The question of the use of "T" rails on paved streets has been so widely discussed during the past two or three years that one would suppose that some definite conclusion might have been reached by this time. But the conditions affecting its use are so varied, and the results due to these conditions so much in conflict, that it is difficult, perhaps impossible, to formulate a positive rule. Aside from this, the municipal and the electric railway engineer consider the subject from radically different points of view. To the electrical railway engineer the track appears the absolute property of the railway, from the use of which teams should be prohibited. The municipal engineer considers the streets as a whole, provided for every kind of traffic, the track being merely an incident. Consequently, although the use of the "T" rail is growing in favor, many conflicting statements are made as to its

adaptability for city streets, and in some instances after a trial it has been rejected. In order to obtain the opinions of authorities on this subject, communications were addressed to the engineers of Denver, Colo., Los Angeles, Cal., Boston, Mass., Birmingham, Ala., Milwaukee, Wis., Indianapolis, Ind., Columbus, Ohio, and Minneapolis, Minn.—cities in which "T" rail is used on the paved streets. As these cities differ widely in geographical position and climatic conditions, as well as in the nature and character of their traffic, any data thus obtained

Fig. 13.—High-class electric railway bridge masonry, Clifton Extension, Philadelphia and Garrettford Street Railway.

should aid in reaching a conclusion. With the exception of Birmingham, Columbus, and Boston, the replies received all express unqualified approval of the "T" rail. The city engineer of Birmingham states that the grooved rail gives greater satisfaction; the chief engineer of Columbus does not think "T" rails in his city satisfactory; while the chief engineer of surface lines of Boston states that the results are satisfactory except where the teaming is heavy. Here snow often

forces the travel to the track, and rutting of the pavement next to the rail occurs.

The arguments deduced in favor of a "T" rail on paved streets are as follows: It is, of course, the section which gives the greatest strength with the most economical amount of metal. The section being symmetrical, the load comes directly over the center of the rail, and the head being full and deep, insures a long life. It is more easily laid, and on

Fig. 14.—A piece of trackwork of the Philadelphia and Garrettford Street Railway, Collingdale Extension, constructed by the Company's own force.

account of the perfection reached in the type of splice bars in use, better joints can be obtained and held. These arguments all apply to ordinary steam railway construction, but when it is realized that the characteristics stated produce good track surface, good alinement, and a true and permanent gage, of inestimable value on paved streets, their force becomes of striking importance.

Moreover, a "T" rail gives a flangeway that will take a wheel with the M. C. B. flange; the paved groove, being gritty, allows teams to

turn out with great ease; and "T" rail tracks are less noisy—additional advantages which cannot be easily overlooked.

It is also claimed that the "T" rail offers less resistance to traction, that better installation can be had, and that track expense, on account of the difference in the weight and type as compared with the girder and grooved rail, is at a minimum.

On the other hand, where "T" rails are in use, special blocks or bricks must be employed in paving adjacent to the rails; and where

FIG. 15.—Portion of track of the Ardmore and Llanerch Street Railway, illustrating good construction by general contractors.

heavy teams are compelled to follow the track, this paving is worn down at the rails, and ruts and hollows form.

Briefly, it may be stated that where the travel is light or the street of sufficient width to allow the heavy traffic on the sides, "T" rail construction may be used with advantage; but where there is a congested and heavy vehicular traffic along the tracks, the use of "T" rail is not advisable, as there is no known pavement that will "stand up" under such conditions, and the cost of street maintenance is heavy.

Where "T" rails are used on paved streets, the discussion narrows to

the type of "T," the character of paving adjacent to the rails, and of track foundation. Regarding the type of "T," the factor to be considered is a rail of sufficient depth to remain fairly rigid under a load, and also to permit the foundation for the paving material to rise above the surface of the ties. This requires the use of either a heavy standard section or a high "T"—commonly known as the "Shanghai" section. A Shanghai rail under ordinary conditions will lose gage and alinement, but with proper paving and occasional tie rods these disadvantages are

Fig. 16.—A piece of faulty track construction, where light "T" rails are used with vitrified brick paving without foundations. Ties laid on natural soil.

overcome, and even the lighter sections allow sufficient depth for paving of any character.

Where the "T" rail is at all permissible and the traffic is heavy, the best section appears to be Lorain No. 91, high "T," as the base, 6 inches in width, and the height, 7 inches, insure sufficient stability and depth. Where the traffic is light and a paving block not over 4 inches in depth will answer, and where considerable special work is required, the heavy standard sections will be found even more economical than a light high "T."

The paving adjacent to the gage of the rail must be of such a character as to form a groove of sufficient size to allow the wheel flange to move without obstruction. If a natural stone block is used, it is best chiseled to shape. If the block is manufactured, it is formed with a nose or groove that will give the necessary clearance.

Where the vehicles "track" T rail construction, the paving, no matter what its character, should have a guard of stone blocks adjacent to the rail, this being the material which will best endure wheel wear.

In conclusion, it may be well to state here that as the problem of the "T" rail is largely one of proper paving, good concrete foundations should receive careful consideration.

DISCUSSION.

Mr. E. M. Nichols.—Is not one of the advantages of good ballasting the distribution of the load on the soft earth?

Mr. Franklin.—Yes, and good drainage.

Mr. Cyril J. Hopkins.—Mr. Franklin has referred incidentally to economy of power, but has dwelt at length and shown a good deal upon the subject of track structure. Perhaps a further reference to rolling stock and economy of power might not be out of order here.

I have just made some tests on interurban cars (weighing 36 tons empty) running between Atlantic City and Ocean City, and find an appreciable saving in energy with ball bearings on the main car journals as compared with plain bearings. When making an average of 1.3 stops per mile on the interurban section, some 15 miles in length, an average saving of 13 per cent. was recorded for the ball bearing car over the plain bearing car; ten complete trips with each of the cars having been made. Considering the elements in which energy is dissipated, 9 per cent. was saved in the starting resistance over that consumed in the plain bearing car resistance, 13 per cent. in the motors and gears, and 17 per cent. in the brakes. This means that the starting resistances are less liable to give trouble; the motors and gears heat up that much less, and the brakes used receive less wear and tear.

These facts are explained by the statements that the ball bearing car can be started a little more quickly over the control period, thereby wasting less energy in starting resistance, the motors have the current on for a shorter period during the whole trip, thus wasting less energy due to their inefficiency, and, for the same total time consumed over the trip, the ball bearing car can be run to a lower speed before braking than is possible with a plain bearing car.

Investigation of that portion of the trip in which there is the greatest length of run between stops, namely, between Missouri Avenue (Atlantic City) and Pleasantville, a distance of about five miles, showed a saving of over 20 per cent. with the same average speed for each type of car.

Since the trips we have already worked up include practically the maximum number of stops, it has been decided to make another set of test trips, comprising the minimum number, inasmuch as the actual number of stops over the whole

system in regular service with passengers are less than the maximum number in the special tests made by us to date, so that there is every reason to think that under these conditions the saving will be more than 13 per cent.

In making these investigations, I made it my duty to sit by the motorman and record his controller operations. He had not a great deal of education in the direction of economy of energy. If he wanted to use up time he would throw the controller on slowly, possibly taking eighteen seconds in doing so; but if he wanted to hurry up, he would put it on in six seconds. Again, in using up time he would not only start slowly, but perhaps run the first portion of the distance between stops on half speed, throwing the controller full on toward the end of the run, thus making it necessary to put on brakes at high speed and wasting energy in that way.

It seems to me that great advantages would accrue from putting up signs to "Coast" at proper points along the line, in that way educating the motormen, preventing them as far as possible from going ahead, in any haphazard way, and wasting a large amount of energy through carelessness.

(Mr. Franklin further stated that the ballast was spread by carts or wagons in the same manner as would be done for a macadam road. It was then rolled with a steam-roller and the ties and rails were placed upon it. If the road is to be a double-track one, the ties and rails are laid directly on the subgrade for the first track, and the ballast is usually delivered by cars from this track and can only be rolled for the second track. This method also applies to where track connections are made with the crusher or with the railroad delivering the ballast cars. From his own experience he stated that in all cases where ballast is carted, or unloaded from cars directly on the roadbed for a second track, the use of a steam-roller in compacting the ballast is economical.)

PAPER No. 1073.

INDUSTRIAL PROGRESS OF MEXICO.

JOHN BIRKINBINE.

(Active Member.)

Read June 15, 1909.

SIXTEEN years ago it was my privilege to present before the Engineers' Club "Notes on Engineering in Mexico,"* in which were made comparisons of conditions noted during two professional visits to that country, in 1882 and 1893. The interval between these two visits covered the commercial awakening of Mexico, brought about largely by the construction of nearly 7000 miles of railroads in eleven years, but the changes then noted, although marked, were scarcely more pronounced than those evident during subsequent visits, and at the request of the Committee on Information the following data, gained by trips through our neighbor republic in 1905 and 1909, are offered to supplement the original paper.

It has not been my privilege to view Mexico as a tourist, and some features of especial historical or picturesque interest included in excursions are unfamiliar, for members of an organization of engineers know that business trips offer limited opportunities for sight-seeing. However, one short and four extended journeys in our neighboring republic included eighteen of the thirty-one political divisions, and, while many prominent cities and industrial centers are familiar, much of the country traversed has been away from railroad routes or established highways. During these journeys investigation of the resources of the country, the possibility of their exploitation, the industrial development, and the capabilities of the people have been studied.

The population has increased from 11,600,000 in 1890 to 15,500,000 (estimated) for 1908, and material advancement has outstripped the augmented population. Railroad extensions have opened areas of agricultural territory previously remote from markets where the products could be disposed of, and these avenues of traffic have made possible the exploitation of mines which otherwise would have lain dormant, while numerous industries, some on large scale, have been

* See PROCEEDINGS for July, 1893, vol. x, No. 3, pages 222 to 240.

established. Improved paving, water-supplies, and sewerage systems have added to the health and prosperity of cities, for although many ancient aqueducts are still in use, a number of these interesting examples of early engineering are abandoned because they supply water of undesirable quality or under insufficient head or in too limited quantity, and piping has been, or is being, substituted in modern water-supplies. Electricity has been liberally introduced as a source of light and power, many haciendas having individual generating plants and much of the

FIG. 1.—Masonry aqueduct and masonry bridge adjoining large hacienda in the State of Morelos, Mexico.

current being produced by hydro-electric installations, some of which are of phenomenal importance. The capital city is enjoying the advantage of the extensive drainage canal and tunnel referred to in 1893 as then under construction; its formerly dimly lighted streets and buildings are well illuminated by electricity, this same medium being applied to power purposes, and in a number of offices and homes electric heaters reduce the morning and evening chill which detracts so much from the comfort of visitors to this city of 450,000 inhabitants.

Foundations are engineering problems in the city of Mexico, as it is built on the remnant of a drained bog, and a prominent example is furnished by a monument on the "Paseo de la Reforma," which is now passing through the third effort to secure a stable base to support a tall shaft in a vertical position.

However, there are large buildings of steel skeleton construction with stone or brick face, such as market-houses, the "La Mutua" office building of five stories equipped with elevators, the new \$5,000,000

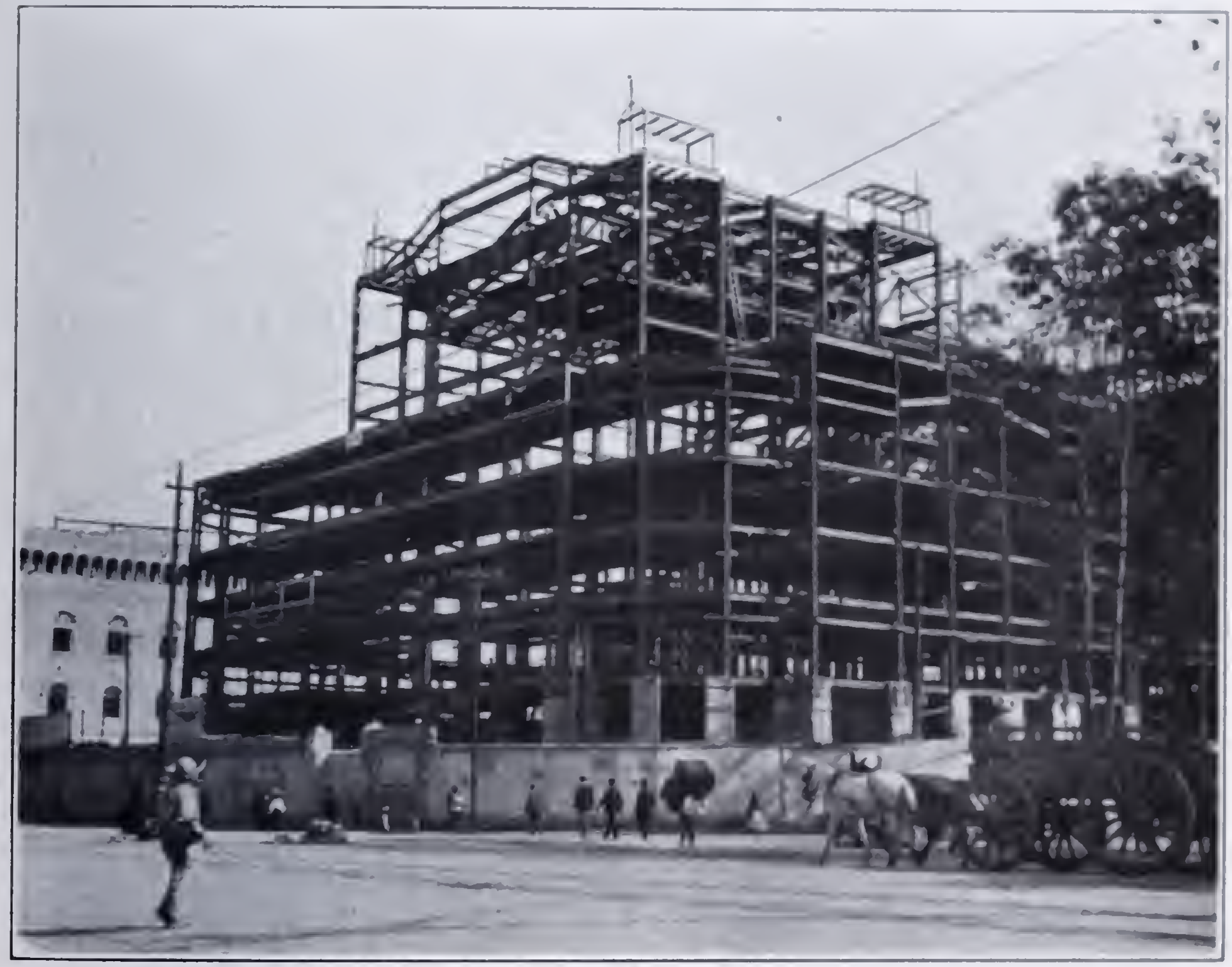

Fig. 2.—Steel skeleton structure of the National Theater in the City of Mexico. Note the heavy sections used.

theater now being erected, the skeleton being steel from Germany, and an interesting structure is the Geological Museum, with double spiral stairways of ornate design in metal.

To the boggy formation the residents of the city of Mexico attribute the moderate damage resulting from earthquakes, "temblores," for, while the wave motion is occasionally severe, the "wicked vertical shake" which demolishes buildings is moderated. There are several important structures much deformed from settlement, and one large

church decidedly out of plumb, which have withstood repeated shocks due to earthquakes that caused buildings to vibrate, high-tension feed wires to swing in contact so as to short circuit, and impelled the people to seek safety in open places.

A marked advance is in the urban and suburban traffic of the capital city, where the "cochero," who formerly by whip and whistle encouraged mules to draw small cars, is generally replaced by the motorman, who controls the operation of modern American-built trolley cars from overhead wires, but mule power transportation is prevalent in smaller cities.

The base of the statue erected on the Zocalo, a plaza of the City of Mexico, to commemorate the work of Enrico Martinez, the engineer who designed the drainage system, is utilized to exhibit the standard meter length, and on it is cut the latitude, 19° 28′ 4.5″ north; the longitude, 99° 6′ 42.6″ or 6h 38m 8.6s west from Greenwich; and the altitude above sea-level of 2269 meters, equivalent to 7439 feet. Mexican cartography, however, is usually referred to the meridian of the capital city.

The journey made in 1882 was in advance of railway construction, and tedious rides over alkali plains supporting only sage brush and cacti growth, or through rugged mountain passes, were made in "diligencias" or on horseback. Within late years these deserts have supplied "guayule," a formerly neglected plant, from the root and stems of which rubber is obtained. In 1904 "peons" were glad to collect this and pile it by the railroad for $8 to $10* (Mexican) per ton, for which service they now receive $34, and the large plants for treating it pay $70 to $75 per metric ton delivered. Botanists are studying the propagation of the plant, and the Japanese are reported to have taken an interest in its development. Up to the present time the collection of "guayule" has been characterized by the improvidence which prevails in Mexico as elsewhere, and the supply may become lessened unless the growth is liberally encouraged and protected.

In 1882 the country had less than 300 miles of railroad (or 2.7 per cent. of the present mileage), confined to the initial enterprise, the Mexican Railroad connecting Vera Cruz with the capital of the republic, a construction which reflects credit upon the persistency of the British capitalists who expended upon it thirty-seven million dollars, or about

* Except where specifically stated to the contrary, prices mentioned in this paper are in Mexican currency, and may be considered as double gold value.

$125,000 per mile, and equal credit upon the engineers who, with the limited experience and equipment available forty years ago, planned and directed this interesting work.

As early as 1837 a concession for a railroad connecting the capital and the Gulf was granted, but abandoned after surveys had indicated its difficulties, and two subsequent concessions were canceled before 1865, when, under Maximilian, the Imperial Mexican Company started work, and in two years built 47 miles out of Vera Cruz and 86 miles out of the City of Mexico. This concession was forfeited by the fall of the Empire, but in 1868 the Mexican Railway undertook the completion of the road, 264 miles in length, and connected Vera Cruz and Mexico City at the close of 1872.

Of the 4000 miles of railroad added in the interval from 1893 to 1908, much consists of branches of and feeders to existing lines, but several important extensions have been completed, a considerable portion of narrow-gage road has been converted into standard gage, and gradients or alinements have been improved.

An important addition is the transcontinental standard-gage railroad, crossing the Isthmus of Tehuantepec by a practically north and south line, less than 200 miles in length. The National Railroad of Tehauntepec connects Coatzacolcos, or Port of Mexico, on the Gulf with Salina Cruz on the Pacific Ocean, each having modern terminals equipped with electric cranes, while the harbor improvements, which cost $100,-000,000, permit of quick dispatch for large vessels.

Its strategic value is augmented by the Vera Cruz and Isthmus Railroad, which connects it with the railroad system of Mexico, and by the Pan-American Road being built along the Mexican Pacific coast to Guatemala.

Hawaiian sugar is shipped to the United States in bond over the Tehuantepec Railroad, and preparations are being made for double-tracking the road to meet increasing traffic, as this route is nearly 1000 miles shorter between Atlantic and Pacific ports in the United States than that via the Isthmus of Panama. The road is equipped with oil-burning locomotives; the fuel being conveyed by thirty miles of pipe-line from Minatitlan to Port of Mexico, where large refineries are operated.

Another feature is the extension of the Mexican Central lines to Manzanillo on the Pacific coast, giving this road a transcontinental line from Tampico on the Gulf of Mexico, through San Luis Potosi, Aguascalientes, Irapuato, and Guadalajara. Another advance is the con-

struction, now in progress, of a railroad along the Pacific slope which will ultimately connect Guaymas with the above extension. But perhaps the most notable change is the acquisition by the Mexican Government of most of the railroads of the republic by means of a merger, the concentration of the management under a commission named by the President, and the control of traffic charges.

While the Government of Mexico has been generous in granting concessions to railroads, it has exacted rigid compliance with contracts. An evidence of this is a substantial through truss steel bridge spanning

Fig. 3.—One span of a steel truss railway bridge at Balsas, Guerrero, forming the terminus of the Cuernavaca Division of the Mexican Central Railroad. The flat boats shown are utilized to convey freight down the Rio Balsas to various settlements and mining centers.

the Balsas River as the terminal of the Cuernavaca Division of the Mexican Central Railroad, over which no trains pass, as there is no connection beyond, but the concession provided for this bridge, and it remains in place, used only by foot passengers, who tread the ties.

A number of railroad bridges are of large size and some of the highway bridges are of impressive design. At the popular resort of Cuernavaca a modest stream is crossed by a masonry arch bridge 110 feet high, the abutments being enlarged to form circular concourses, or "glorietas" with fountains.

Within short distances one sees the modern and the crude in compari-

son; thus, in passing through a cañon, the Cuernavaca Division of the Mexican Central Railroad uses a curved steel bridge, while a few miles

FIG. 4.—Curved steel trestle in a cañon on the Cuernavaca Division of the Mexican Central Railroad.

below is a suspended foot-bridge made from vines and pieces of wood lashed by rope, and close by is a dam constructed of facines (large wicker baskets) loaded with stone, its function being to supply irrigating ditches.

As previously stated, the topographical features of Mexico require that in railroad construction long tangents over waterless deserts alternate with difficult cañon work, bridging arroyas which each year by erosion change their cross-section or form new channels, and climbing mountainous divides.

Little advance has been made in the use of metal ties, to which reference was made in the first paper, the piles of these lying beside the roadbeds unused indicating that their expected superiority has not been demonstrated.

The use of coal has reduced the number of wood-burning locomotives, although on some roads vegetable fuel is still employed, and the liberal application of mineral oil as locomotive fuel suggests the favor in which this is held.

Oil obtained from wells in the State of Vera Cruz has practically displaced other fuel for locomotives on railroad lines reaching the Gulf of Mexico and on the Central Railroad system south of Aguas-Calientes. The large "gushers" which attracted attention by venting uncontrollable volumes, and the efforts to quench the fire which consumed immense quantities of oil, have directed attention to this resource as developed in the State of Vera Cruz, where fuel oils sell at $25 per metric ton at the wells, and are finding a market for internal explosion engines and many other uses.

The application of producer gas to engines is growing in favor, anthracite coal and coke being imported for this purpose, and in the State of San Luis Potasi charcoal is made in meilers and in kilns for such use.

Much of the electrical energy applied in the City of Mexico is obtained from the Mexican Light and Power Company, mainly from an installation recognized as the Necaxa plant, and the report of this company shows that on January 1, 1909, its contracts covered:

Public lighting, 1810 arcs	1,470 H. P.
Private lighting, equivalent to 338,500 16 c. p. lamps	27,250 H. P.
Power motor units	22,783 H. P.
Electric heaters	1,085 H. P.
Tramways	8,610 H. P.
Total power connected	61,298 H. P.
Add current distributed to El Oro mines and vicinity	17,775 H. P.
A total of	79,073 H. P.

At the hydro-electric plant (which is supplemented by a steam in-

stallation in the City of Mexico) the maximum power generated during 1908 was 45,000 H.P., or nearly 60 per cent. of the total connected load. The water-power units in place have a combined capacity of 50,000 H.P., which by installations now in progress is expected to be increased to 66,000 H.P., and it is planned to further augment this each year by adding a 16,000 H.P. generator, until three such have been installed.

A large earthen dam, being constructed by sluicing into the embankment clay, sand, and rock loosened by hydraulic giants, is in the course of erection. This dam was planned to have a length of over 1000 feet, a maximum height of 190 feet, a top width of 54 feet, and a maximum base of 965 feet, of which 365 feet is the central clay core. In May two-thirds of the 2,130,000 cubic yards required for the dam were in place, when a slide occurred which moved about one-half of this material, or 720,000 cubic yards, 350 feet into the interior of the dam. This accident will delay the completion of the structure and may limit considerably its storage capacity, and possibly reduce the head on the power station, which was planned to be 1453 feet. Additional reservoirs on other streams are being constructed to store water and divert it to the main dam by means of canals and tunnels.

The mountainous character of central Mexico offers numerous opportunities for the development of water-power, for the descent of most streams is rapid, but the unequal distribution of rainfall into wet and dry seasons requires impounding water on liberal scale when large volumes are to be utilized.

Records of rainfall in the Valley of Mexico, which have been kept for thirty-two years, show an average annual precipitation of 579 millimeters (22.8 inches), the minimum and maximum being 332 and 893 millimeters (13.07 and 35.16 inches) respectively. The major portion of the rainfall occurs in the months of June to September inclusive; the averages for the various months showing:

Month.	Millimeters.	Inches.
January	3.25	0.13
February	6.54	0.26
March	12.2	0.48
April	19.66	0.77
May	45.66	1.8
June	101.12	3.98
July	112.93	4.45
August	117.70	4.63
September	101.32	3.99
October	40.53	1.6
November	10.52	0.41
December	7.43	0.29

The unequal distribution of precipitation appears from the following table:*

RANGE OF ANNUAL RAINFALL IN THE VALLEY OF MEXICO FOR THIRTY-TWO YEARS, 1877 TO 1908 INCLUSIVE.

Month.	Millimeters.	Inches.
January	0 to 20	0 to 0.79
February	0 to 41	0 to 1.61
March	0 to 63	0 to 2.48
April	0 to 65	0 to 2.56
May	6 to 126	0.24 to 4.96
June	26 to 193	1.02 to 7.6
July	48 to 210	1.89 to 8.27
August	40 to 346	1.57 to 13.62
September	43 to 205	1.69 to 8.07
October	3 to 151	0.12 to 5.94
November	0 to 32	0 to 1.26
December	0 to 114	0 to 4.49
Year	332 to 893	13.07 to 35.96

However, some streams have well sustained volumes, and an unusually favorable opportunity for hydro-electric development on the Balsas River in the State of Guerrero was visited. This stream drains an area above the town of Balsas of approximately 17,000 square miles, chiefly in the mountainous sections of Guerrero, Oaxaca, Puebla, Tlaxcala, and Morelos, and its genesis is the perpetual snow on Popocatepetl and Ixtachihuatl, whose peaks have elevations approximating 17,000 feet above sea-level, while most of the water-shed is from 1500 to 10,000 feet above tide.

A measurement at the Mexican Central Railroad bridge at Balsas at low stage showed a discharge of 2668 second feet, or 0.16 second foot per square mile of drainage area, which the topographical and climatic conditions appear to verify; but for most of the year a continuous discharge of 5500 second feet, or 0.32 second foot per square mile, is estimated as available.

*Since the above was written, portions of northeastern Mexico have suffered from phenomenal floods. It is reported that at Monterey 14 inches of rain fell in forty-two hours, and a few days thereafter 20.16 inches fell in ninety-eight hours, or a total of 34.16 inches of rain in one hundred and forty hours.

We may imagine the result in a district where 3½ inches is the average August precipitation, and appreciate the flood conditions by recalling the three days in 1889 when Johnstown was engulfed and central Pennsylvania devastated by a rainfall ranging from 6½ to 9 inches.

A dam 82 feet high, spanning a distance of 300 feet between cañon walls, is planned to back water in a pool over 12 miles long, and a canal 2 miles in length will deliver water from the pool to a power station under a head of 121.5 feet. A second power about three miles below will back water to the upper station by a dam, giving an available head of 29.5 feet.

To meet varying demands, to allow for peak-loads, and to utilize the normal flow of the river as much as possible, installations in the two plants of 60,000 H.P. and 16,000 H.P. respectively are planned.

Fig. 5.—Gorge of the Balsas River which it is proposed to span by a dam. The precipitous cliffs shown rise for over 1000 feet above the stream, whose width at the promontory is narrowed to approximately 300 feet at normal water-level.

The hydro-electric plants on the Balsas River are intended to supply power and light to towns, to important mining centers, and to a large sugar-growing territory in the State of Morelos, where there are numerous extensive haciendas. It is also expected to utilize the electricity generated on the Balsas River to displace steam, to improve transportation facilities within haciendas, and to connect these and towns with existing railroads.

Another prospective application is that of elevating water by means

of electric pumps to increase the area of irrigated lands, some installations of this character being in use in the sugar country.

A prominent product of Mexico is sugar, and cane can be grown at an elevation of 8000 feet above sea-level, but it does not tassel above 4500 feet; and, although the soil is excellent, the shallow scratching which much of it receives from the sharpened logs used as plows, and

Fig. 6.—Group of buildings on a large sugar hacienda in the State of Morelos, Mexico.

the limited fertilization applied, reduce the yield below that of Hawaii. On one side of a mountain range convenient to railways may be seen a large "hacienda," equipped with modern machinery of approved type, while on the opposite side crude rolls, driven by water or animal power, crush the cane.

Some of these modern haciendas employ steam-plows for cultivating the ground; have equipments of steam-derricks, cane and bagasse carriers, rolls, vacuum pans, centrifugals, filter presses, and other acces-

sories, economical boilers, high-duty steam-engines, and handle their cane and products on narrow-gage railroads by steam locomotives.

Other mills are ancient, and in some are old Spanish rolls of copper; open-air evaporation is used; and, in crystallizing, the sugar in earthen molds is blanketed with clay to extract the molasses. Many haciendas produce no marketable sugar, but convert the cane into alcohol (aguardiente).

Pretentious textile works are also in evidence within a short distance of wooden looms, wool wheels, and hand cards operated in cane or adobe

Fig. 7.—Interior of a sugar hacienda in the State of Morelos, Mexico, showing sugar-cane being handled from ox-carts by steam derricks, and in the foreground bagasse drying for use as fuel.

shacks occupied by the natives, who thus produce excellent "sarapes," "rebosas," or other woven goods of wool clipped from the numerous herds of sheep and goats, or of cotton harvested from large areas under cultivation.

The first Mexican journey was through sections then remote from railroads, and the one made a few months ago was distant from both railway and wagon roads, where the crude methods noticed in northern Mexico twenty-seven years ago were found in use in the mountains of Oaxaca. Among these is the ancient Catalan forge, in which iron ore is

fed to an open charcoal fire intensified by blast supplied by trompe, in which falling water entrains air. The bloom made in the fire is wrought under a helve hammer operated by a water-wheel, and rewrought into bars or anchovies, which are marketed locally for from three to five cents gold per pound.

Some of the charcoal blast furnaces mentioned in "Notes on Engineering in Mexico" are also active, and the delicate castings from furnaces or iron puddled with pine wood are produced in the manner therein described. In several prominent cities scrap furnaces are operated with fuel supplied by gas producers and connected with rolling mills producing merchant iron, and foundries and machine shops furnish much of the repair and some of the new work required. As a rule, these industries are inclosed to prevent pilfering, and workmen are searched upon leaving the plant.

At Monterey, in the State of Nueva Leon, a modern iron and steel industry was established in 1901 by the Cia. Fundidoro de Fierro y Acero de Monterey, S. A. The plant consists of one blast furnace, 80 by 18 feet, one Bessemer converter, three 35-ton open hearth furnaces, one composite mill to roll beams and shapes or rails, a merchant mill, spike works, foundry and machine shop, and other accessories.

The blast furnace is fed with iron ores obtained in northern Mexico, the mixture ranging from 57 to 62 per cent. of iron, and closely averaging 60 per cent. iron. The coke used is one-half domestic, one-half foreign, and limestone is brought from nearby quarries. The domestic coke is produced from coal mined in the State of Coahuila, 200 miles from Monterey, and for smelting purposes, owing to the percentages of ash and sulphur, is mixed with cokes shipped from the United States and Europe to Tampico, and from thence 322 miles by railroad to Monterey.

Pig-iron is cast in sand when not supplied as direct metal in ladle cars to the Bessemer converter (formerly a feature of the Pottstown, Pennsylvania, basic Bessemer plant), where it is partially blown, and is then carried by ladle to open hearth furnaces already charged with scrap; this duplex process accelerating the rate of conversion and augmenting the open hearth output; the cast ingots passing through soaking pits to the blooming and roughing mills, heating furnaces, and then to the composite trains. When visited, the mill, which has a capacity double that of the blast furnace and converting equipment, was running on an order for 20,000 tons of 85-pound open-hearth steel rails for the Mexican National Railroads.

The general management is by Mexicans and most of the employees are natives, but department heads and many skilled workmen are foreigners. The labor basis at the plant is $1.50 Mexican per day, equivalent to 75 cents gold, but the number of employees exceeds that usually found in similar works in the United States. In 1907 nearly 18,000 tons of steel ingots were produced and 30,000 tons of manufactured steel, mostly open hearth, were turned out.

Practically all the domestic coal produced in Mexico is mined in the State of Coahuila, near the United States boundary, where about 1,500,000 tons are obtained annually. In 1907 the output of the Coahuila coal fields was 1,265,719 metric tons, about one-third of which was converted into coke. Exploitations have followed the mineral for 4500 feet on a slope, and a shaft 930 feet deep is in use.

The towns, railroads, and other improvements, for which these coal deposits are responsible, have transformed a desert country into an industrial center, most impressive to one who first knew the coal as a mere prospect.

The coal costs about $2.00 gold per ton to mine, and, owing to the percentage of ash, washing is necessary to prepare it for coking, 20 to 25 per cent. passing away in the tailings; hence, two tons of coal as mined are necessary to produce a ton of coke, and this product commands about $6.50 gold per ton at the ovens.

But the fuel requirements of Mexico are more than double the output of the Coahuila fields, and domestic coal and coke compete with foreign fuel at the capital and other centers of consumption on the main plateau. The railroad freight rate from the Coahuila mines to the City of Mexico, 835 miles, is $4.00 gold; the same amount is charged on foreign fuel carried 264 miles from Vera Cruz, but in the latter case the fuel is elevated from sea-level to the capital, 7500 feet. Fuel is, therefore, an important problem, and one purpose of the recent journey was to inspect prospecting work and reconnaissances in Oaxaca, which for one and a half years have been carried on under the direction of my son and associate, J. L. W. Birkinbine.

This is neither the time nor the place to discuss the details of the exposures made by the use of diamond drills and many exploratory workings in searching for coal and iron ore in the State of Oaxaca. But it may be of interest to state that three bituminous coal basins of considerable extent and large deposits of rich iron ore have been located, and that from one of the fields a dense coal, burning without smoke, is obtained, intimating a close approximation to anthracite. In this coal

the volatile matter is low, but, as in all Mexican coals, the ash is high.

The Coahuila coals are classed as cretaceous, while the Oaxaca coals are believed to be in the Upper Jurassic formation.

As the Oaxaca coals are found at altitudes ranging from 6000 to 7000 feet above sea-level and within 300 miles of the capital, they offer opportunities for cheap transport as compared with the Coahuila coals mined at an elevation of 1500 feet and carried over 800 miles to the City of Mexico.

Reconnaissances demonstrate that, notwithstanding the mountain-

Fig. 8.—Flying buttresses of the ancient cathedral in Cuernavaca, reported as having been constructed in the sixteenth century.

ous character of the country, satisfactory railroad routes are obtainable which, besides bringing the Oaxaca coal into market connection, can be extended to the Pacific coast.

While the mines of Mexico have been the cause of many extravagant statements, the country is rich in mineral, and most of the States are producers of importance. In the paper which this article supplements one of Mexico's great iron ore deposits was described, and a résumé of important mines or quarries would fill many pages of the "Proceedings."

In the mountainous sections of Oaxaca and Guerrero covered in the last visit the mines produce gold, silver, copper, lead, antimony, and

other minerals; one lead smelter visited being equipped with American impulse water-wheels working under a head of water of 60 feet and operating American rotary blowers. This smelter was supplied with water-jacket and metal tuyeres, and all of this installation had been transported on the backs of animals for 75 miles.

Peopled by a succession of generations, which for centuries have depended upon wood or charcoal made therefrom as fuel, little valuable timber remains, although the Oaxaca mountains sustain a fair growth of gnarled and stunted trees; the herds of sheep and goats preventing the development of any decided new growth.

This paper is merely a sketch outline of general features which could be filled in with engineering details, including extensive harbor improvements, governmental or municipal buildings, revised alinement and gradients of railroads with their bridges and tunnels, design and equipment of manufacturing industries, extent and product of mines, mills, and haciendas, description of water-power installations and distribution of electrical current, public water-supplies, drainage systems, etc. But from what is presented it is evident that Mexico will have wonderful progress to exhibit in celebrating next year its centennial of independence, or rather commemorating the spark struck by Hidalgo in September, 1810, from which resulted the flame of patriotism which was not extinguished during fifty years of internal strife between warring factions led by ambitious leaders, but was fanned into renewed fervor by the unsuccessful effort, backed by European influence, to establish an empire under Maximilian in 1866.

At the Centennial Exposition in Philadelphia in 1876, General Porfirio Diaz represented the republic of Mexico. Since that time he has, with the exception of four years (1880 to 1884), been the President and practically the dictator of our neighbor republic, guiding it toward a future which should place Mexico as a permanent feature of "governments of the people, by the people, for the people," which we trust will characterize the entire western hemisphere.

In two interviews with President Diaz I was impressed with the intimate detailed knowledge he possesses of his country's needs and possibilities, and his apparent enthusiasm over any project which promises national advancement. He not only analyzes figures, but understands drawings, an accomplishment unusual among men in public life.

When Cortez landed in Mexico and initiated the Spanish conquest, the knowledge that Columbus had found the land we know as North

America was less than thirty years old. But the conqueror found numerous impressive temples and constructions which evidenced a civilization covering centuries, and now Mexico is uncovering ruins which offer fertile fields for archæologists.

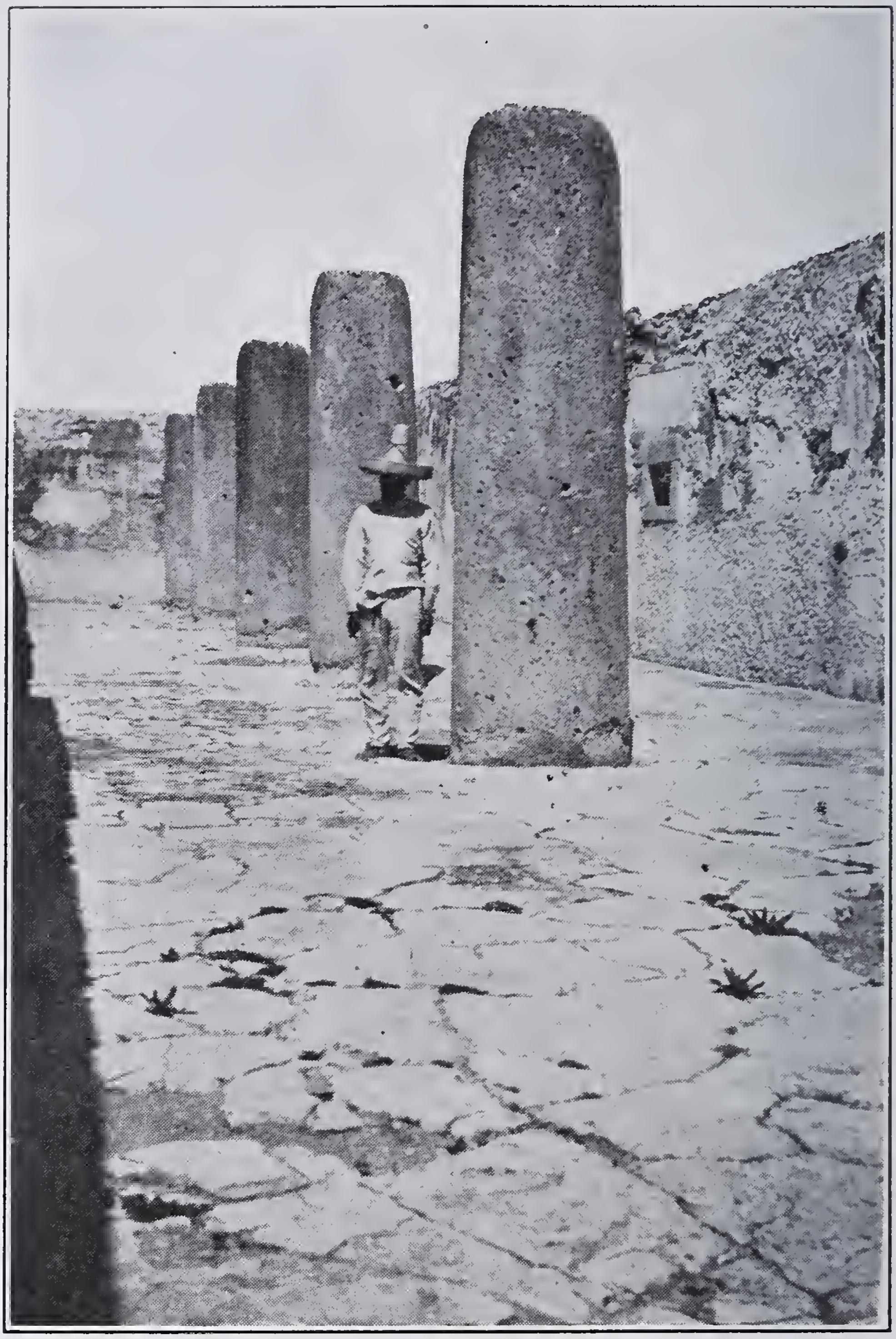

FIG. 9.—A portion of the ruins of Mitla, Oaxaca, which have been excavated, showing the Hall of Monoliths.

The Mitla ruins, near Oaxaca, present interesting examples of mosaic work on heroic scale, done by people of whom no authentic history has been discovered, and in other localities explorations are being conducted under governmental authority.

During the journey through Oaxaca, I lived among people who trace

their history back to the sixth century, and traversed territory evidencing that in the past it had sustained a population greatly in excess of that now occupying the towns, pueblos, and ranches.

Details concerning the country traversed and the crude methods

Fig. 10.—Part of the ruins of Mitla, Oaxaca, showing a portion of the East Corridor of Mosaics. Note the intricate pattern, the small pieces of stone being so well laid as to have withstood the ravages of centuries.

followed by the interesting people in Oaxaca are given in the paper "A Trail through the Mountains of Oaxaca, Mexico," by H. E. Birkinbine, who was my companion and assistant in the investigations.

The methods of agriculture and industry, and the means of travel, mainly rugged mountain trails, carry one far back in history; and the

knowledge that the same methods were in use in Oaxaca when our own progressive country was a wilderness awakens interest. But when evidences of advancement are noted where modern appliances have been introduced, and the possibilities of good soil and the equitable climate due to the altitude are recognized, the future of southern Mexico looms bright, and the same progress shown in other sections of the republic may be anticipated.

Paper No. 1074.

A TRAIL THROUGH THE MOUNTAINS OF OAXACA, MEXICO.

HENRY E. BIRKINBINE.

(Junior Member.)

Read June 15, 1909.

This paper is not technical, but, as the title indicates, treats of a portion of the republic of Mexico concerning which little information has been published, although this region was peopled long before the section of North America in which we live was known. An effort will be made to describe the physical features, the people, and their industries and habits, as noted while on a trail through the mountains in the northwestern part of the State of Oaxaca.

The State of Oaxaca, whose capital bears the same name as does the State, lies southeast of the City of Mexico, and, with Chiapas, forms the southernmost portion of the republic of Mexico. Its coast line, lying entirely along the Pacific Ocean, has a length of 300 miles, and the railroads within the State do not cover more than 370 miles. The topography, which for the most part consists of series of mountain ranges with intervening valleys, varies from sea-level on the Pacific coast to 10,800 feet, the average elevation probably exceeding 5000 feet above tide.

This State has an area of 35,392 square miles, about four-fifths of that of Pennsylvania, and is settled by a million people, of whom approximately one-third are meztizos and whites, and the remainder composed of fourteen Indian tribes, the Zapotecas and Mixtecas being by far the most prominent. The route traversed on the trip was mainly through the country and towns settled many centuries ago by the Mixtecas, who speak a language of their own. A few Mixteca words are given to indicate the character of the tongue and the difference between it and the Mexican, or Spanish, language.

As instances: "ñu" is the Mixteca word for the Spanish "lumbre," meaning "fire"; "tree," which in Spanish is "arbol," the Mixtecas call "ñutu"; while "hombre," the Spanish for "man," they designate as "te." Also "corn-fodder," which is known by Mexicans as "zacate," is termed "dndojo"; "cuñu" replaces the Spanish "carne" for "meat";

"mountain," "cerro" in Spanish, is called "yucu"; and the familiar word "pan," meaning "bread," becomes "yxtatila."

The Mixteca peons, a peaceful, music-loving race, wanting in hygiene and method in their life and labors, have unusual powers of strength and endurance. The men carry heavy burdens and travel all day at a smooth running-walk, over hills, along valleys, and through streams, for from 25 to 37½ cents gold a day. As an instance, it was related that a "mozo," man-servant, carried a barrel of sugar over the mountains to the camp, a distance of eighteen miles, and also that a native bore a

Fig. 1.—Typical topographic features in the vicinity of Huajuapam, Oaxaca.

barrel of cement along a sidewalk in the City of Mexico. With the aid of a piece of rope, and using the "sarape," native blanket, as a cushion, the Indian carries burdens which in this country require the services of two or three men. A case experienced was that of a "mozo" bearing upon his back a metal steamer-trunk, filled with clothing, as well as a large dunnage-bag full of "sarapes" and blankets, from the railway station to the second floor of the hotel, a mile away. An example of their endurance, even when young, is that of a barefoot Indian girl, ten years of age, walking thirty-five miles over the rough mountain trails in a day and a half to earn one dollar gold a month.

Despite the strenuous exertion on a day's trail of from thirty to forty miles over the rugged mountains, and the heavy burdens borne, the Indians seem to take little rest. At night the "mozos" sit around the camp-fire and chatter long after every one else has "turned in," and in the early morning, when the camp awakes, they have been astir for some time and have prepared the pack train for the day's work. Along the trail their meals consist of "tortillas," thin cakes made of corn-meal ground between stones, which they buy at the villages passed through, while in the towns they can purchase for two cents gold a meal of soup, meat, "frijoles" or beans, and "tortillas."

On the trail one meets man, woman, or burro, each carrying a load of approximately the same weight, but the woman often has the additional burden of a child slung over her back in a "rebosa," a thin native shawl with a fringed edge.

The tenacity with which the people cling to the primitive methods is illustrated by the fact that when iron wheel-barrows were first brought to the workings, the miners would wheel them out of the opening with a load of coal or waste, and then, turning the implement upside down and bearing it on their heads, would trot back into the drift. Another case brought to attention was that of a peon, who, accustomed to the use of the Mexican plow, consisting of a sharpened log with a stick attached for a handle, cut off one handle of a new American plow.

In towns, or occasionally on the trail, the costumes differed according to the wealth and position of the wearer; those of the men varied from up-to-date European suits to the white, or once white, cotton garments, much resembling pajamas; the conical hats ranged from felt with elaborate gold or silver embroidery to straw; and where shoes could not be afforded, they either went barefoot or wore sandals. The clothing of the women was of the latest European fashions or the native low-necked bodice and skirts, much frayed about the edges, and their head-coverings were lace "mantillas," or scarfs, or the domestic "rebosas," those who could not obtain shoes usually being barefoot.

Occasionally a man is seen in the "charro" costume of short jacket, bright colored belt, and tight-fitting trousers which button or hook along the outside of each leg, these garments being sometimes decorated with gold or silver buttons or heavily embroidered with braid of the same metals.

The high peaked hats with broad turned-up brims, which are worn by both men and women while on the trail, serve the double purpose of a protection from the sun and a convenient method of carrying in the

brim, so as to be readily accessible, small change, trinkets, cigarettes, and fruit, or at times another hat is perched on the peak.

The "sarape," from which the "mozo" is never separated, is used as a blanket at night, to wrap about the upper portion of the body and to cover the mouth in the cool of the evening and early morning; lies on the ground nearby when the owner is working; is carried over the forearm or shoulder while trailing; and is used as a cushion when heavy bundles are carried.

FIG. 2.—Group of Mixteca Indians with local band, showing the character of the habitations.

On the trail other travelers are met, usually "peons" driving pack trains of burros carrying large boxes, bags, jars, or bundles, and often accompanied by the young animals, which solemnly trot along beside their mothers, stopping to gaze at the stranger with wide-open eyes. Sometimes one meets a man riding a fine horse, preceded by a "mozo" carrying a gun and followed by another bearing a wicked looking "machete." From each traveler is received a "buenos dies," or "buenos noches," the Spanish for "good day" and "good evening," and also a raising of the hat from the "peons," men and women, who will

pass on without making a mistake in the manufacture of another hat, which they weave from strips of palmetto leaves while walking or riding over the trails.

The narrow, winding, steep trails lead up and down the sides of the mountains, from whose summits are obtained impressive views of the valleys lying a thousand feet or more below. In the valleys, however, the trail broadens out into a road, "camino real," which leads across the valley with its arroya and through the towns, and on which are seen occasional "carretas," two-wheeled carts of wood doweled together with wooden pins and tied with ropes, drawn by a pair of plodding yoked oxen.

During the wet season the water from the heavy rains, in its course to the river-bed, cuts deep "barrancas," or arroyas, with nearly vertical sides, in the soil, and to cross these gulleys the trail winds around until it reaches the end of the "barranca," or a place where the slope of the bank permits a descent to the bottom, and further along a climb up the opposite bank.

Along both sides of the road, bordering the fields or defining the village streets, rows of aloes, or maguey plants, from which is obtained the native drink of "pulque," grow to large sizes, and when blooming send up from the center of the plant a long shoot, about fifteen to twenty feet in height, from whose top are put out symmetrical branches bearing clusters of flowers and giving the effect of a lofty branched candlestick. The prickly pear, which in our climate is nursed in flower-pots, grows to trees from fifteen to twenty feet high in Oaxaca.

In the valleys, on both sides of the roads, lie the fields in which are raised wheat and maize, and in some protected sections sugar-cane flourishes, while anise-seed is occasionally seen growing. The perpetual summer of the region permits of one field being plowed while those adjoining show the green blades springing from the ground or a crop ripe for harvest. Modern agricultural implements were not used by these people, the tilling of the ground being usually accomplished by means of a plow, said to resemble that used by the ancient Egyptians, where a sharpened log, sometimes shod with iron, fitted with a stick for a handle, scratches a shallow furrow in the soil. These plows are drawn by a pair of yoked oxen urged by a thorn fastened in the end of a long stick. The field may also constitute a threshing floor, where, after the grain has been trodden out of the hulls by two or three horses and a burro hitched together and driven in a circle with the driver as the

pivot, the first favorable breeze is utilized to waft away the chaff, the grain falling to the ground when the mixture is tossed into the air. After a corn-field has been harvested, the stalks, or "zacate," are stored in the branches of trees to prevent them becoming the food of animals allowed to roam, while the corn is conveyed to conical adobe bins.

The habitations beside the trail are usually of cane with thatched roofs, and some of these have along the ridge-pole a line of earthenware

Fig. 3.—Sugar rolls made of copper and operated by animal power. They are claimed to have been introduced by the Spaniards at the time of the Conquest.

jars, broken vertically down the centers, overlapping so as to prevent the leakage of rain-water. Nearby some of these shacks are hemispherical bake-ovens, with a small hole in each, built of stones set in lime mortar, for the Indians burn their own lime.

From some of the huts passed issued the noise of the wooden looms weaving the "sarapes" with wool cut from the ranging herds of sheep and goats, carded, spun, and dyed by hand; while from others came the whirr of the modern sewing-machines, and the agencies of these implements can be seen in all the large towns.

The outskirts of the villages are composed of scattered huts built of cane and sometimes inclosed by organ cacti planted in rows so as to form fences; while in the towns the houses, as a rule, are constructed of sun-dried adobe bricks manufactured nearby, and some are also plastered with lime mortar, often painted, the predominant colors being pink or pale blue. The roofs, instead of being thatched, as in the outskirts, are constructed of tile made in the vicinity, or of large, square, flat bricks resting on "vigas," or wooden beams, laid across the tops of the walls with merely sufficient slope to carry off the rain-water. The principal streets are paved with cobble-stones, as is also the "plaza," or public square, near the main church, where the people have their market.

The church is always the most prominent feature of the town, its bare walls and white towers rising above all other buildings, and, at the points on the trail from which the town can first be seen, are placed crosses, which passers-by decorate with vines, branches, and flowers. Wayside shrines and crosses also give evidence of the religious sentiment of the people.

Parian, elevation 4900 feet, the puebla, or small town, from which the start of the journey was made, is a collection of adobe or cane huts, whose roofs are thatched with split aloe leaves or grasses. It is built about the station where the narrow-gage, wood-burning locomotive of the Mexican Southern Railroad connecting Puebla and Oaxaca pauses for wood and water after climbing through rocky gorges, beside tumbling streams, and passing through the "tierra caliente," or hot country, where may be seen the graceful palms and green fields of sugar-cane.

Mountain horses and a pack train of mules and horses were in waiting to carry the party with their tents, provisions, and luggage over the steep, narrow, and often rocky trails across the mountains, whose crests attain elevations above the sea of 8000 to 9000 feet, and which, with their foot-hills, separate the various towns from one another. To relieve those wearied by horseback-riding, a chair built so as to be supported by poles resting on the shoulders of carriers had been provided, with "mozos" in sufficient numbers to act as relays.

The horses and mules, having lived among the mountains, were surefooted and safely traveled over steep, rocky slopes, along narrow sidehill paths, or through stony stream-beds; the only misfortune occurring when a pack-horse, in trying to free himself of his load by bucking, lost his footing on the trail along the mountain-side and rolled into the

river below, wetting the contents of the suitcase lashed to his back and causing the camp that night to resemble a "dressed" man-of-war. For the good of the riders as well as of the horses, it was considered advisable to dismount when descending especially steep or rocky trails, the animals being led by means of long lariats about their necks.

At Nochixtlan, elevation 7200 feet, a town of 4500 people, 27 miles from Parian, a stop was made at the hotel, a one-story affair whose brick-paved rooms with high ceilings opened onto a court paved with cobble-stones. About 6 o'clock that evening the bells in the nearby church began ringing, two bands started playing, and occasionally a cannon was discharged, a preliminary celebration of the following day's anniversary of the granting of the new constitution to Mexico in 1857. These noises were intermittent, ceasing for a while and then breaking out anew. One band did not wait for the other to complete its selection before starting to play, but each gave its own piece in its own time and key while walking from place to place on the public "plaza," and the bells were also independent of the bands. At night the inhabitants lighted rockets and threw them into the air to choose their own courses, and next morning, when the journey was continued, the celebration had not abated.

Outside of the town are a number of hills whose crests are littered with shards of broken ancient pottery, some carved and others painted and enameled with bright colored figures and fancy designs. On the summits of these hills, from what are claimed to be graves, are obtained small idols carved out of stone and drilled through the back to accommodate the thongs by which the idols were carried. Some of these images consist of the head only, but others show the figure in a position of squatting on the heels with the knees protruding in front, the hands being clasped or the arms folded over the breast, and some have a crown upon the head while the features vary from decidedly Egyptian to Asiatic.

At Santa Maria Tiltepec, a little town at the foot of one of the mountain ranges, consisting of probably forty cane or adobe thatched roof huts and situated about forty miles from the railroad, stands a large stone church whose elaborately carved façade contains winged images in niches, and whose interior includes ornate decorations and gilding, as well as an organ, showing the hold of the church upon the scantily clad inhabitants of the vicinity. In the wall around the church as well as in the side walls of the structure are inserted stones with intricate carvings, which were claimed to have been parts of an older edifice,

FIG. 4.—Interior view of damaged dome of sacristy at Teposcolula, Oaxaca. The ornamental character of the stonework is well illustrated.

while well up on the side of the building is set a tablet bearing the date 1689.

Teposcolula, elevation 7500 feet, a town with a population of about 5000, located 28 miles from Nochixtlan, the next stopping-place, gave evidence of having once been of material importance, being reported to have at one time been the capital of the State. Here stands a church, bearing the date 1763, with an attached cloister, and also the ruins of an older church. Fluted sandstone columns, from thirty to forty-two

Fig. 5.—Masonry arched trail bridge near Tepòscolula, Oaxaca.

inches in diameter and twenty-five to thirty feet high, support handsomely carved arches with spans of about thirty feet and a dome, from which part has fallen, a good-sized tree growing from the rim of the hole. The columns are built up in sections, each formed of a number of segments made of such size as to be transported from the distant quarries on mule-back.

On one side of the town, crossing a stream, is a bridge of masonry plastered with lime mortar, giving the appearance of concrete; and in another locality is a bridge formed by building stone piers and resting

upon these huge logs thrown across the stream between two pairs of tall sabino trees.

Near a pueblo, called San Pedro de Salinas, are salt fields where the saline water oozing through the earth is evaporated, leaving a deposit of salt on the top soil, which is scraped into piles by the inhabitants and placed in holes in the ground filled with water, dissolving the salt. After the earth has settled, the brine is decanted into a vessel and carried to the huts, where evaporation by boiling leaves the domestic condiment.

Tlaxiaco, a town with an elevation of 7000 feet, having 8000 inhabitants, with 4000 people in the surrounding pueblas, was reached after a ride of thirty-five miles from Teposcolula, being ninety miles from the railroad or nearest continuous wagon road. Claiming it to date from the sixth century, the residents are proud of their town, which is the political head of the district and boasts of two four-wheeled passenger vehicles, which, however, must remain within the valley, where the trails are sufficiently wide to permit of their use.

This progressive town has separate schools for boys and girls, and its streets are illuminated by electric lights, the current being supplied from the municipal power-plant containing dynamo, engine, and a 30 H. P. boiler using wood as fuel. The machinery was brought over the mountains with great difficulty, trees and "dead men" being employed to assist the oxen in hauling the sections, which were placed on rollers.

Tlaxiaco supports an orchestra as well as a good band, the natural talent for music being illustrated by the fact that many of the performers are boys. The music-loving character of the people was demonstrated by finding that the disturbance of one's rest at 3 o'clock one bright moonlight morning by the soft music of the orchestra's guitars, mandolins, violins, flutes, and clarinets was because the night was so beautiful the members of the orchestra felt they should serenade through the town.

Another novel experience was that of sitting on the balcony when the band was giving a serenade and looking down upon the dark-skinned musicians in peaked hats, white clothes, and a "sarape" about the shoulders, standing in an open circle and playing familiar music with modern instruments by the aid of the light of a candle resting on each music-stand. This band has the advantage of having interested in it one of the prominent citizens, who sends away for the music, varying the selections from waltzes to marches, and even including operatics and classics.

It was stated that at the Fourth of July celebration of the American

Fig. 6.—Panoramic view of the city of Tlaxiaco, Oaxaca, and surroundings.

engineers employed by the Oaxaca Iron and Coal Company, into which the officials and residents joined most heartily, the band from a town thirty miles away came into Tlaxiaco playing one of Sousa's stirring marches.

Three years ago, when the engineers of the above company first settled in Tlaxiaco, an American was a curio, but now there are in the town English signs, including those of "shu shine" and "barber shop."

A caller upon one of the prominent citizens found in his parlor long mirrors, carpet, parlor furniture, and a piano, all of which must have been carried over the mountains by "mozos" or mules. There were also in the town several billiard tables, which had been brought from the railroad in a similar manner.

One of the town "plazas," where the market is held on Saturdays, is a square paved with cobble-stones and having in the center a fountain from which some of the residents obtain their supply of water and carry it to their homes in jars. This, with two other similar fountains, constitutes the town water-supply system. On market days the "plaza" is crowded with 4000 to 5000 people, who spread their wares upon mats laid over the stones and will sell their stock, or trade the fruits and cane of the hot country for the pottery, "sarapes," etc., of the towns.

On Saturday night, after the market is over, the pigs of the town clean up the "plaza" refuse, and a Sunday morning's form of excitement is the arrest of the pigs, if the officers succeed in their efforts to catch the animals.

A sport of the Indians is "pelote," or hand-ball, played with a ball made of cloth. Some knock this against the side of a house, having courts marked out in the dirt, similar to racquet; while others have a game resembling tennis, using a line as an imaginary net, with courts marked out in the dirt on both sides of this line. When two Americans played "pitch and catch" on the "plaza" with baseball and gloves, the natives left the shops and formed an aisle up and down which the ball traveled, with a fringe of people two and three deep; and a wild pitch, which struck a stone and, glancing off, hit a native boy on the thigh, caused only laughter and joking in a tongue which could not be understood.

The friendly spirit of the people was also shown by viands sent to our table, such as turkey, boned, minced, and stuffed back into the skin, a roast young pig, and various kinds of "dulce," or desserts.

Leaving Tlaxiaco to visit some of the coal deposits, which were being exploited by the company previously mentioned, the trail was similar

to that leading from the railroad, and after crossing the rugged summits of a number of hills, their steep sides were descended to the Tlaxiaco River near its gorge, where several workings were located. Other openings were visited near Mixtepec, a collection of huts and stores

Fig. 7.—Flashlight taken in the coal drift, from which a semi-anthracite coal is obtained.

about a church, where coal seams were being investigated, the miners using a carrier similar to a stretcher to remove the coal and waste from the drifts. In locating the properties the company was compelled to have a geodetic survey made, selecting a base-line, and tying it to governmental triangulation stations where possible.

Many of the trees in this vicinity have hanging from their branches a fungus, much like our southern moss, which hides the leaves; and from the branches of other trees grow varieties of orchids, the plant resembling the clustered spines of a pineapple top and suspending a chain of bright-colored flowers.

Fig. 8.—Gorge through which the Mixtepec River makes rapid descent. The proportions are indicated by comparison with the individuals on the cliffs and rocks.

Near Mixtepec the camp for the night was made by the Mixtepec River, where this stream leaves its fringe of "sabino" trees in the rolling country and enters a gorge whose nearly vertical walls are about 170 feet high and 230 feet apart.

Mina Consuelo, a little settlement in a narrow valley between high hills, from whose crests the coyotes howl at night, is where most of the exploitation has been done, and a welcome sight upon coming over the summit of a hill was that of the Stars and Stripes flying beside the Mexican tricolor above the office and chemical laboratory, which had been installed by the company on account of the distance the operations were from any established laboratory. Two diamond drills, a shaft, and a number of drifts are utilized to prove the amount and quality of coal obtainable.

After visiting the workings at Mina Consuelo, a start for the railroad

Fig. 9.—Organ cactus (candelabra) trees along the trail in western Oaxaca.

was made, and the character of the vegetation changed. Banana and palm trees were seen, fields of sugar-cane were passed, and occasionally the trail, which passed through innumerable palmettos, was left for the welcome shade of large trees of candelabra cactus, which have a pulpy trunk supporting a number of branches, forming a tree about thirty feet high with a spread of the same distance.

Passing through Huajuapam de Leon, a town next in importance to Tlaxiaco, a stop for the night was made at Chila, a little pueblo, where early in the morning the soft plaintive music of an orchestra was heard,

growing louder as from a nearby church came a funeral procession. A number of women and children, each with a small bouquet, preceded the chief mourners and the coffin, which was borne on the shoulders of men, who also carried flowers, and followed by the orchestra. Even the musicians carried small bunches of flowers, those playing the violin and 'cello holding them in the hand with the bow, and on account of the length of his instrument the player of the 'cello had its base supported by an assistant, while he played with its stem resting upon his shoulder.

Continuing the journey and obtaining beautiful views of the mountain ranges and valleys from among the palmettos, which grew either close to the ground or as the stems of branching trees, the town of Acatlan was reached. Here the horses were reluctantly left behind, and seats were taken in a coach which five mules, urged by a "mozo" riding a sixth, pulled over the mountain on a steep, winding road made by cutting into the hillside and filling in back of retaining walls of masonry and overcoming an elevation of 2,500 feet in five miles. Although the wheels of the vehicle were so loose on their axles that a breakdown seemed imminent and inevitable, especially when the mules were driven at a gallop down the mountain side, a safe arrival was made at Mucio

FIG. 10.—Wagon road ascending mountain face near Acatlan, Puebla; average grade about ten per cent.

Martínez, the terminus of the "Ferrocarril de San Marcus y Huajuapam de Leon," a railroad which connects at Rosendo Márquez with the Mexican Southern Railroad to Pueblo, but does not touch either of the towns named in its title. During the latter part of the ride the discomforts of the coach were forgotten in the enjoyment of a view the blue sky-line of which was broken by the peak of Malenchi and the snow-caps of Popocatepetl, Ixtaccihuatl, and Orizaba.

ABSTRACT OF MINUTES OF THE CLUB.

Business Meeting, May 1, 1909.—The meeting was called to order by the President at 8.35 p. m., with 125 members and visitors in attendance. The minutes of the Business Meeting of April 17th were approved as printed in abstract.

The President announced the death of Mr. Wm. P. Henszey, Active Member of the Club since May 17, 1884, as occurring on March 23, 1909.

Following a report of the tellers on election, the President declared the following elected: Jacob Lynford Beaver and Henry L. McMillan to Active Membership; Edward Morris Bassett and Malcolm Roderick Maclean to Junior Membership, and Thomas Gray Phinny to Associate Membership.

Mr. Francis D. West, visitor, presented a paper on "The Sanitary Control of Filter Plants," which was discussed by Messrs. Emile G. Perrot, Wm. Easby, Jr., E. M. Nichols, Richard L. Binder, and Marshall R. Pugh. Upon motion of Mr. Develin a vote of thanks was extended to Mr. West.

Upon motion, the meeting adjourned at 10 o'clock p. m.

Business Meeting, May 15, 1909.—The meeting was called to order by the President at 7.45 p. m., with 96 members and visitors in attendance. The minutes of the Business Meeting of May 1st were approved, as printed in abstract.

The several amendments to the By-Laws, as proposed by the Committee on Rules, were brought up for discussion and amendment, and a number of minor changes were carried. On account of lack of time, it was moved that an adjourned meeting of the Club, for continuing this discussion, be held on Saturday, May 22d. It was also announced by Mr. Gwilliam that at this meeting an amendment would be offered, increasing the dues of the members, and reasons for this action were given.

Mr. T. Kennard Thomson, Visitor, presented the paper of the evening, entitled "An Informal Talk on Caisson Foundations for Bridges and Buildings," which was followed by a short discussion by Messrs. E. M. Nichols, W. F. Ballinger, and others. Upon motion of Mr. Easby, a vote of thanks was extended to Mr. Thomson.

The meeting adjourned at 10.30 p. m.

Special Adjourned Meeting, May 22, 1909.—The meeting was called to order by the President at 8.30 p. m., with 52 members in attendance.

The several amendments to the By-Laws, proposed by the Committee on Rules, were brought up for discussion and amendment, and were considered from Article IV, Section 7, to Article V, Section 1. Article VI, Sections 1 and 2, were also considered, and the amendment, raising the dues of all members was amended, so that only the dues of the Resident Members be increased.

Upon motion the meeting adjourned at 11.15 p. m., to continue on Tuesday evening, May 25th, at 7.30 p. m.

Special Adjourned Meeting, May 25, 1909.—The meeting was called to order by the President at 7.50 p. m., with 25 members in attendance.

The several amendments to the By-Laws, proposed by the Committee on Rules, were brought up for further discussion and amendment, and were finally adopted in the form contained in the notice for the meeting of June 5th.

Upon motion of Mr. Wm. Easby, Jr., it was decided that the vote upon these amendments be taken in two parts: first, covering all the proposed amendments except the increase of dues of Resident Members; and, second, a separate vote on this increase in dues.

The meeting adjourned at 10.30 p. m.

Business Meeting, June 5, 1909.—The meeting was called to order by the President at 8.30 p. m., with 125 members and visitors in attendance. The minutes of the Business Meeting of May 15th were approved as printed in abstract.

The President announced the death of Mr. C. T. Wunder, Active Member of the Club since April 6, 1907, which occurred on May 28, 1909.

The President again called attention to the Engineering Convention, to be held in Harrisburg on June 9th, 10th and 11th, and requested that all members who intended to be in Harrisburg at this time, communicate with Mr. Charles F. Mebus, chairman of the delegation from this Club.

It was announced that the Board of Directors had elected the following to serve as the Committee on Nominations:

H. W. Spangler, *Chairman;*
E. M. Nichols,
William C. Kerr,
H. F. Sanville,
St. George H. Cooke.

Following a report of the Tellers, the President declared that Edgar P. Dout, Carroll Williams Simon, and Charles F. Thacher, Jr., had been elected to Junior Membership. The Tellers also reported that 156 legal votes had been cast on the Amendments to the By-Laws, as proposed by the Committee on Rules April 7, 1909, and subsequently amended, with the following results: For all Amendments except increase of dues, carried, there being 140 votes for and 11 votes against, 101 votes being necessary for approval. For increase of dues, not carried, there being 70 votes for and 83 votes against, 102 votes being necessary for approval.

Two papers were presented, "The Industrial Progress of Mexico," by Mr. John Birkinbine, Active Member, and "A Trail Through the Mountains of Oaxaca, Mexico," by Mr. Henry E. Birkinbine, Junior Member. The papers were followed by a few remarks by Mr. James Christie, Mr. J. W. Ledoux, and Mr. John Birkinbine.

The meeting adjourned at 10.05 p. m.

ABSTRACT OF MINUTES OF THE BOARD OF DIRECTORS.

REGULAR MEETING, May 15, 1909.—Present: President Dallett, Vice-Presidents Devereux and Easby, Directors Clarke, Cochrane, Quimby, Twining, Hess, Gwilliam, Mebus, the Secretary and the Treasurer.

The Treasurer presented his monthly report, which showed an average net loss in running expenses for each of the preceding four months of \$78.00. To meet this deficit, it was decided that an amendment be presented to the Club, raising the dues of Resident Active and Associate Members to \$30.00, and other classes of members in like comparison, and that it be announced that this amendment had the indorsement of the Board.

Following the reading of two letters from Dr. Henry Leffmann, Chairman of the Trustees of the Bond Redemption Fund, the Finance Committee was appointed to meet the Trustees to formulate changes in the rules governing the purchase of bonds.

The resignations of Mr. Charles E. McInnes and Mr. E. Haldeman Finnie were read and accepted.

Mr. Edward W. DeKnight was granted permission to reprint a paper by Mr. H. S. Righter on the Track Elevation through Wilmington, Delaware, provided credit be given to the Proceedings of the Club.

A request from the Library of the University of Illinois, to exchange publications, was referred to the Library Committee, with power to act.

A letter was read from Mr. F. Herbert Snow, President of the Engineers' Club of Central Pennsylvania, announcing that a Convention of Engineers would be held in Harrisburg from June 9th to 11th, and requesting that a delegation of members from the Engineers' Club of Philadelphia be appointed to attend. Mr. Charles F. Mebus was appointed Chairman of this delegation, and was authorized to notify Mr. Snow of any other members who would attend.

The following Nominating Committee was elected to nominate officers for 1910:

H. W. Spangler, *Chairman*
H. F. Sanville
E. M. Nichols
Wm. C. Kerr
St. George H. Cooke

Upon motion of Mr. Gwilliam, it was voted that the President and Treasurer be authorized to negotiate a sixty-day note for \$3000, to be used to liquidate the present floating indebtedness. It was also moved that the President and Treasurer be authorized to transfer the account to the Colonial Trust Company, or other bank approved by the Finance Committee, if this action assisted in negotiating the loan.

SPECIAL MEETING, June 5, 1909.—Present: President Dallett, Vice-President Easby, Directors Head, Quimby, Twining, Christie, Cochrane, Develin, Hess, Gwilliam, Hutchinson, Mebus, Wood, the Secretary and the Treasurer.

Mr. Christie made an informal report for the Committee on Finance, stating that a conference would be held at an early date with the Trustees of the Bond Redemption Fund, to formulate certain changes in the rules governing the purchase of bonds.

The death of Mr. C. T. Wunder, Active Member of the Club since April 6, 1907, was announced. Mr. Wunder's death occurred on May 28, 1909.

The resignation of Mr. Herman Nieter was read and accepted.

Letters from the Aero Club of America, requesting resolutions to be executed to Wilbur and Orville Wright, were read, and the former action of the Secretary, declining to do this, was confirmed.

The resignation of Mr. Charles S. Redding, manager of the Club, was read and accepted as of June 15, 1909. A vote of thanks was extended by the Board to Mr. Redding for his efficient services.

Mr. Twining brought up the question of the election of the new House Manager, and, upon motion of Mr. Gwilliam, it was moved that the House Committee be authorized to appoint a House Manager, with power to assign duties, with the approval of the Board.

Special Meeting, June 8, 1909.—Present: President Dallett, Vice-President Devereux, Directors Quimby, Twining, Christie, Gwilliam, Hutchinson, Mebus, Wood, the Secretary and the Treasurer.

Following a report of the Badge Committee, design No. 12, submitted by Bailey, Banks & Biddle, was adopted as the official Club badge. The Badge Committee was discharged. The method of the purchase and sale of these badges was left to a Committee, composed of the President, Secretary, and Treasurer.

Mr. Twining announced that Mr. Charles Mish had been appointed House Manager, at a salary of $60.00 per month, in addition to room and board. Upon motion of Mr. Christie, the salary of the Secretary was fixed at $30.00 per month, and the salary of the Treasurer at $10.00 per month.

Special Meeting, June 24, 1909.—Present: President Dallett, Vice-Presidents Devereux and Easby, Directors Clarke, Twining, Christie, Develin, Hutchinson, Mebus, Wood, the Secretary and the Treasurer.

The operation of the restaurant was brought up for discussion, and it was finally moved that the restaurant be closed as near after July 1st as possible to open again on or about the middle of September, Mr. Twining, Chairman of the Committee on House, to have charge of the necessary arrangements.

The death of Mr. Wm. Price Craighill, Honorary Member, was announced. Mr. Craighill was elected May 4, 1901, and died January 18, 1909.

The resignation of Mr. George C. Davis was read and accepted.

A letter was read from Mr. Elmer K. Hiles, Secretary of the Engineers' Society of Western Pennsylvania, in reference to the formation of a Committee to recommend a bill to the Legislature, regulating the licensing of engineers. Action upon this matter was deferred.

Special Meeting, July 8, 1909.—Present; President Dallett, Directors Clarke, Twining, Cochrane, Develin, Hess, the Secretary and the Treasurer.

Mr. Twining, Chairman of the Committee on House, stated that a new form

of contract with the caterer had been proposed, and, on account of the satisfactory arrangements, it was moved that the previous motion made at the meeting of June 24th, to close the restaurant, be annulled, and that the contract, as read, be ratified.

The following resignations were read and accepted: Henry J. Lamborn, Leonard C. Holston, James B. Bonner, Wm. J. Donaldson, C. F. Cludius, Harry F. Porter, Wm. L. Geddes, Charles E. Clausen, A. F. Rader, J. M. Herr.

The Treasurer reported that fifteen members had been dropped from the roll for non-payment of dues.

A letter was read from Mr. F. Herbert Snow, President of the Engineers' Society of Pennsylvania, asking that the Engineers' Club appoint a committee of three to coöperate with committees from other organizations, to recommend to the Legislature a bill regulating the practice of engineering. This matter was referred to the President, with power to act.

THE ENGINEERS' CLUB OF PHILADELPHIA

1317 Spruce Street

OFFICERS FOR 1909

President

W. P. DALLETT

Vice-Presidents

Term Expires 1910
WASHINGTON DEVEREUX

Term Expires 1911
WM. EASBY, JR.

Term Expires 1912
PHILIP L. SPALDING

Secretary
W. P. TAYLOR

Treasurer
H. E. EHLERS

Directors

Term Expires 1910	*Term Expires 1911*	*Term Expires 1912*
J. O. CLARKE	JAMES CHRISTIE	GEO. T. GWILLIAM
W. S. TWINING	HENRY HESS	EDW'D S. HUTCHINSON
FRANCIS HEAD	H. P. COCHRANE	CHARLES F. MEBUS
HENRY H. QUIMBY	RICHARD G. DEVELIN	A. C. WOOD

STANDING COMMITTEES OF BOARD OF DIRECTORS

House—W. S. TWINING, GEO. T. GWILLIAM, H. P. COCHRANE, A. C. WOOD, JAMES CHRISTIE.

Finance—JAMES CHRISTIE, PHILIP L. SPALDING, RICHARD G. DEVELIN.

Membership—WM. EASBY, JR., CHAS. F. MEBUS, GEO. T. GWILLIAM.

Publication—H. H. QUIMBY, CHAS. F. MEBUS, FRANCIS HEAD.

Meetings—J. O. CLARKE, FRANCIS HEAD, A. C. WOOD.

Library—WASHINGTON DEVEREUX, H. P. COCHRANE, EDW'D S. HUTCHINSON.

Publicity—GEORGE T. GWILLIAM, W. P. TAYLOR, J. O. CLARKE.

Advertising—H. E. EHLERS, H. P. COCHRANE, CHAS. F. MEBUS.

MEETINGS

Annual Meeting—3d Saturday of January, at 8.15 P.M.

Stated Meetings—1st and 3d Saturdays of each month, at 8.15 P.M., except between the fourteenth days of June and September.

Business Meetings—When required by the Constitution or By-Laws, when ordered by the President or the Board of Directors, or on the written request of five Active or Associate Members of the Club.

The Board of Directors meets on the 3d Saturday of each month, except July and August.

PROCEEDINGS

OF

THE ENGINEERS' CLUB

OF PHILADELPHIA.

ORGANIZED DECEMBER 17, 1877. INCORPORATED JUNE 9, 1892.

NOTE.—The Club, as a body, is not responsible for the statements and opinions advanced in its publications.

Vol. XXVI. OCTOBER, 1909. No. 4

PAPER NO. 1075.

RECENT IMPROVEMENTS IN INCANDESCENT LAMPS.

F. W. WILLCOX.

(Visitor)

Read February 15, 1908. Revised September, 1909.

THE artificial production of light is a branch of science and engineering which is of most extraordinary interest to mankind and has a most profound effect on modern life. This may be fully realized by considering what a hardship it would be for a modern man to give up modern illuminants and use those of his forefathers. Of the expenditures made for the necessaries of life, that for light and illumination is among the largest, as through the employment of artificial light man is able to extend the allotted span of life by from 40 to 50 per cent., adding many hours to the average day which were completely lost to early man.

As an engineering feat, our methods of producing light, however, are not at all creditable, because of the very low efficiency of such production. All improvements in lamps and methods of lighting possess great interest and value, and extensive awards await the inventor who makes improvements.

All are more or less familiar with the course of development of the incandescent lamp; of the early platinum lamps of Edison; and the carbon filament lamp, which, finished invention as it was, has dominated the field of electric lighting for the past twenty years. In this

period nothing was added to or taken away from the lamp, but the methods of production were cheapened and a steady improvement in quality was made.

In the past two years there has been a remarkable awakening, with such radical improvements as to immeasurably promote the supremacy of the incandescent lamp. The Whitney discovery at the General Electric laboratory of the so-called metallizing or graphitizing of the carbon filament by treatment in the electric furnace has given a 2½ w.p.c. lamp equal in life results to a 3.1 w.p.c. carbon filament lamp.

On other improvements the art appears to have reverted to the lines of the early developments, *i. e.*, to metallic filaments, and we have the osmium, tantalum, and tungsten filament lamps giving efficiencies from 2 to 1 watts per candle.

It is interesting to note that the inventor of the Welsbach mantle (the incandescent lamp's most serious rival) was the one who started the present metallic filament development. About six years ago Dr. Auer von Welsbach undertook to improve upon the carbon lamp by returning to the use of metals. He selected for his lamp the rare metal osmium, which has a high melting-point, and with which excellent lamps of 1½ w.p.c. have been made, their chief limitation being the expense and rarity of the metal.

The solution of the problems and difficulties involved in the production of the osmium lamp has assisted materially in the development of the later filament lamps, such as the tungsten.

Before passing to a description of the new lamps it will be well to briefly review the present incandescent lamp and its method of manufacture.

It is just twenty-seven years ago since Edison gave his first public exhibition of incandescent lighting at Menlo Park. During this twenty-seven years the lamp has had a remarkable growth. In 1880 the number of incandescent lamps made and used in the United States hardly exceeded twenty-five thousand, while in the past year, 1907, there were between sixty-five and seventy million lamps used in the United States alone; and the total number of lamps in the world was over one hundred million. Assuming the average price of the lamp was fifteen cents, this gives a total of over fifteen million dollars annually expended for this one detail of electric lighting service—a most instructive illustration of the great value of the electrical industry.

The incandescent lamp appears to be a simple thing, but in reality it is very complicated, involving in its construction the consideration of

many abstruse chemical, electrical, and engineering problems. The most important part of the lamp is the filament, the light-giving portion or burner, which, as is well known, is composed, in the present lamp, of carbon.

Carbon is not the only substance which can be used for the filaments of incandescent lamps. The number of materials, however, is very small, for two reasons: first, the material must be capable of withstanding a very high temperature, and, secondly, it must be a conductor of electricity. This excludes most materials except carbon and a few metals. Carbon is a very satisfactory material for filaments because it makes a conductor of very high resistance. If we will take the resistance of silver as one, resistance of aluminum will be 2, iron 6, lead 12, German silver 14, graphite carbon 2600.

The production of the filament is one of the most interesting processes in the manufacture of lamps. The early filaments were made from the parchmentized thread; then from strips of cardboard and paper, and later from Japanese bamboo. For many years the bamboo filaments were exclusively used. Strips of bamboo, such as might form the sticks of a lady's fan, were imported from Japan, and these were cut to the desired size of filament by small knives and planes. The cutting work required some eight different operations before the piece was reduced to the required size. This was very expensive and required great care, and even at the best it was difficult to make a filament as uniform in size as the requirements of the lamp demanded.

A marked improvement was made when the present method of making filaments was invented. We now surpass nature at her own game by producing artificially a fiber of any length, size, or shape, and making it thoroughly uniform. We make filaments exactly as the brickmaker makes bricks. We first dissolve cotton-wool in a chemical solution, which after various operations becomes a thick syrup. This syrup is then forced through various sized dies, giving a continuous thread, which, when it is allowed to fall into a jar of alcohol, hardens in this form and makes the fiber for the filament. This, after washing and drying, has the appearance of a piece of horsehair, or, in the larger sizes, of catgut. This fiber is shaped and fitted to the size and type of filament desired. It is then packed in charcoal in crucibles, placed in a furnace, and carbonized in the same manner as charcoal is made.

This produces the completed filament as it was used in the early lamps. The performance of such a filament is, however, limited to the temperature which this piece of charcoal will stand. This temperature

is not as high as is possible with the present type of filament, which is subjected to an additional operation before being used in the lamp. The filament as it now stands consists of a piece of amorphous carbon like charcoal carbon; it is not subjected to what is known as a treating or depositing process, but it is coated all over with a layer of a different form of carbon, known as graphite carbon, and an enlarged sectional view of a broken filament would appear something like that of a lead-pencil.

The depositing or treating process increases the efficiency of the filament in the same way that covering a steam-pipe increases the efficiency. The deposit upon the surface gives a smoother and brighter surface than that of the untreated carbon, and as a result, the filament is a better emitter of light. Just as a hot polished copper rod if covered with lampblack will cool much sooner than one not blackened, so a hot lamp filament with one kind of surface will cool much sooner than one with a smooth polished surface, as a treated filament.

The treated filament, therefore, requires less energy to produce and maintain a certain candle-power than the untreated filament. If we should take a given filament untreated and measure it for candle-power or energy, it would be found to give about 20 c.p. at 80 watts; then if this filament is taken and treated a very little and made up again into a lamp and tested, it will be found to give 20 c.p., with a consumption of only about 65 watts—considerably less energy than before treatment.

Thus completed, the carbon filament of the ordinary 16 c.p. lamp measures about .004 inch in diameter and 10 inches in length. In order to measure and handle such fine filaments many interesting tools have been invented, and with them manufacturers are able to measure accurately to the forty-thousandth part of an inch.

The actual making of the lamp requires some fifty different and distinctive operations, and an equal number of additional handlings for inspections. The chief operations, however, are not many.

The Metallized Carbon or "Gem" Filament.

One way of improving the efficiency of incandescent lamps is by improving the carbon, that is, by making the carbon more durable and refractory so as to give it a higher vapor tension point. Just as ice evaporates more slowly than loose snow, it should be possible to produce different forms and modifications of carbon which would have different rates of self-destruction.

A carbon filament made from cellulose cannot be operated at as high

a temperature with the same deterioration as can carbon which is deposited by high temperature from hydrocarbons, such as gasoline. So we find at the boiling-point of carbon that a modification is produced in the carbon structure which alters its characteristics considerably,

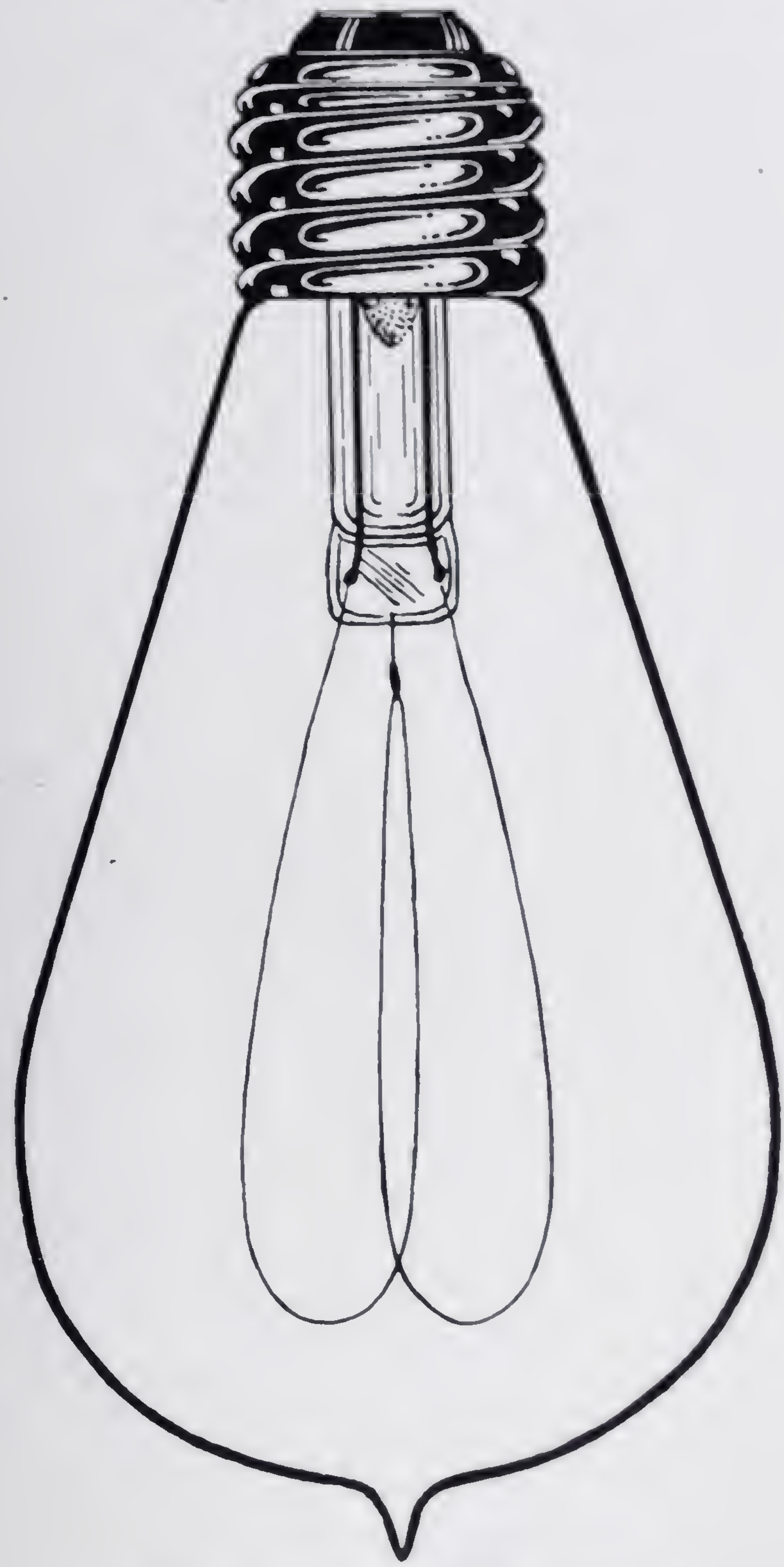

FIG. 1.—The "Gem" lamp.

giving it a positive temperature coefficient of resistance, and much greater refractoriness or stability, so that such a filament can be operated at a considerably higher temperature for the same life and deterioration than the ordinary carbon filament.

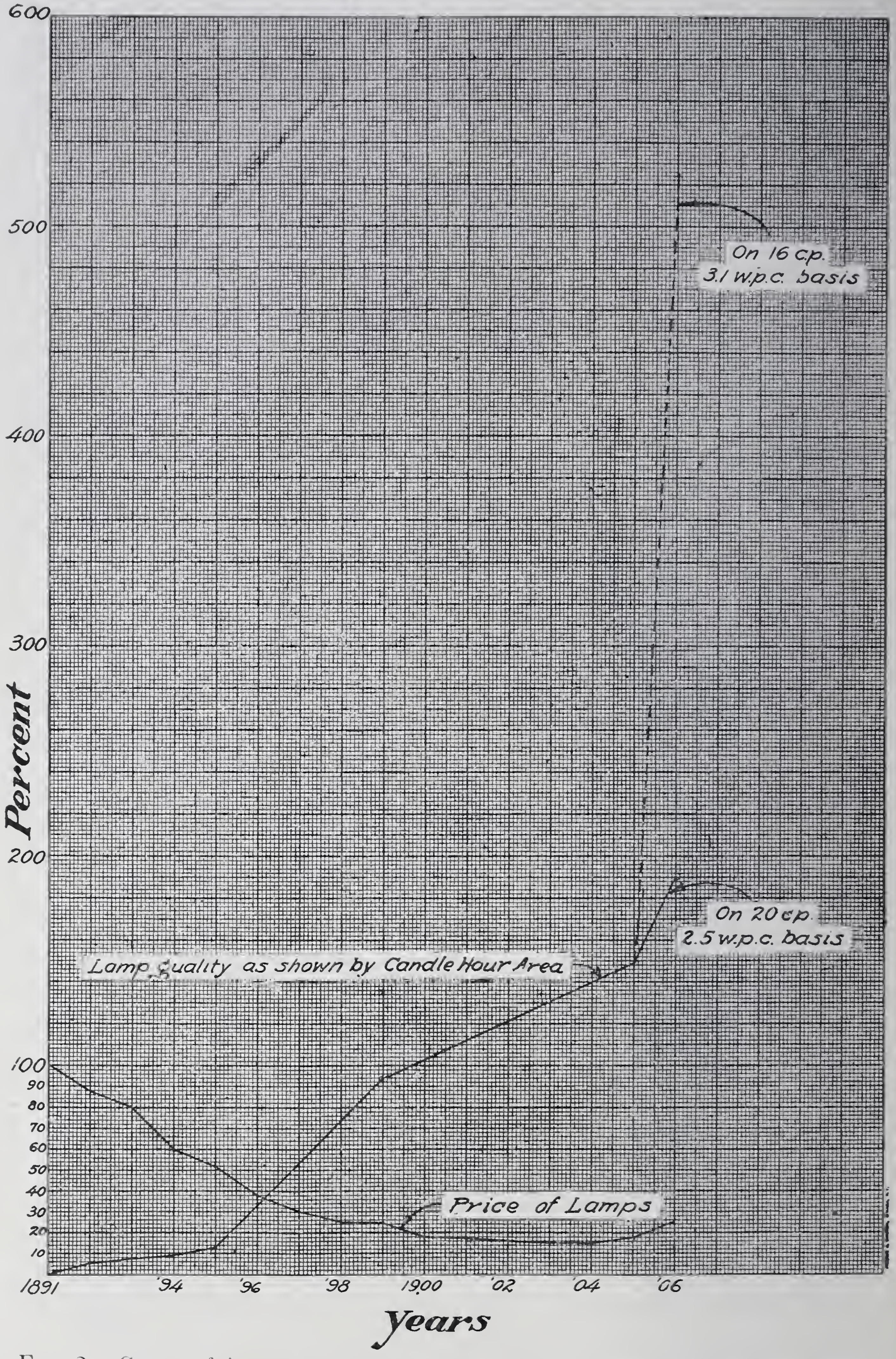

Fig. 2.—Curve of improvement in carbon lamps, showing the great advance given by the "Gem" filament. (Year 1905-06.)

The metallized filament is produced by subjecting the ordinary carbon filament to the temperature of the boiling carbon in an electrical furnace, whereby its characteristics are materially changed. In this metallizing process the untreated filament is first subjected to the metallizing process in the electrical furnace and then removed and treated with the ordinary hydrocarbon treatment already described. After treatment the filament is again metallized, so that each filament is subjected to two metallizings, one before and one after the ordinary hydrocarbon treatment.

The practical effect of this metallizing is to give us a filament which is capable of giving three and one-half times the effective or useful life at the same efficiency as the ordinary carbon filament lamp. Or for the same life it enables us to operate the filament at an efficiency 20 per cent. higher, that is, at 2.5 w.p.c., as compared to the ordinary carbon filament at 3.1 w.p.c. That there is a most notable difference in the results is evidenced by the curve showing improvement in lamp quality shown on the opposite diagram (Fig. 2), where it is seen that in one step there was made an advance equal to that of the last twenty years' development.

The metallized filament is now produced in a number of sizes, from 250 watts down as low as 50 watts. It has principally been employed in the higher candle-power sizes, forming a line of what is known as the "incandescent units." A very efficient combination of the metallized filament lamps with scientifically designed reflectors of the well-known holophane type may be made by which any character of light distribution can be obtained in a simple and effective manner.

The 50-watt metallized filament lamp gives a mean horizontal candle-power of 20, and this is the standard to be adopted by central station service in place of the present 16 c.p. ordinary carbon, giving the customer 25 per cent. more light for the same consumption of energy. A filament of certain size and thickness is necessary to obtain the best effects of the metallizing process, and this process cannot, therefore, give much improvement on small, thin filaments such as are used in low candle-power 100- to 125-volt lamps or 200- to 250-volt lamps.

The value of the metallizing applies particularly, therefore, to low-voltage filaments, such as are employed for car-lighting service, or for street series lighting lamps operated on constant current circuit. The improvement wrought by metallizing carbon filaments appears to be in the reduction in blackening of incandescent lamps. The loss of candle-power in incandescent lamps is principally due to two factors—change of resistance of filament and blackening of bulb.

In the ordinary carbon filament about 55 per cent. of the loss of light is due to blackening of the bulb and 45 per cent. to change in resistance, whereas in the "Gem" filament only 20 per cent. is due to blackening and 80 per cent. to change in resistance.

The Tantalum Lamp.

Tantalum is a somewhat old metallic substance, having been discovered in 1802. As it is practically unaffected by other substances, it was called tantalum because even when in the midst of acid it was unable to take the liquid unto itself, thus resembling the fabled Tantalus—condemned to stand up to his chin in water, which constantly eluded his lips as he attempted to quench his tormenting thirst. It was only in recent years, however, that really pure tantalum has been obtained as the result of experiments by Dr. Von Bolton, of the Siemens-Halske Company, of Berlin, who obtained it from the electric furnace under vacuum, using tantalum for the poles of the electric arcs.

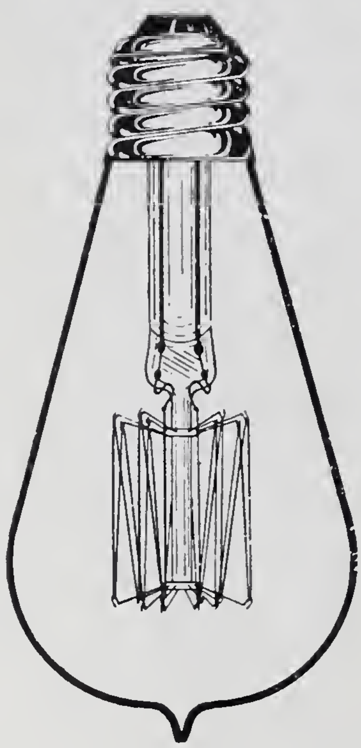

Fig. 3.—The Tantalum lamp.

The pure metal has about twice the specific gravity of iron and is as hard as the hardest steel. It has a very great tenacity, and can be drawn into the finest wire, whose tensile strength is remarkably high, running 133,000 pounds to the square inch, as compared to 100,000 to 112,000 for good steel. Its fusing point is remarkably high, 2500° Centigrade, and this is the chief cause for its excellent efficiency as an incandescent lamp filament.

Tantalum has practically the same electrical resistance as ordinary platinum, so that we have a considerable length of filament for the 110-volt lamp—about 20 inches. The wire is so fine (.0018 inch in diameter) that the weight of the complete filament, two feet in length, is only .022 grain, and a pound of the metal will produce 20,000 lamps.

As metal filaments soften at point of incandescence, it is necessary to have a method of supporting the filament inside the bulb. This is done, as shown in Fig. 2, by looping the wire back and forth through small hooks on the ends of radial wire supports, which are in turn fastened into a central supporting pillar of glass. While the tantalum filament softens under incandescence, and this condition may cause the filament

to be broken, it also enables the filament to be more readily repaired. In many cases of broken tantalum filament a slight tapping on the bulb will cause the broken ends to weld on to the filament and start the lamp burning again.

The tantalum filament gives us an exceedingly brilliant lamp with the excellent efficiency of 2 watts per candle (English Parliamentary) and a useful life on direct current of from eight hundred to one thousand hours or more. On alternating current of 60 cycles or less the useful life of the lamp is reduced to about 600 hours or more, the reduction increasing with the increase in frequency beyond 60 cycles.

The tantalum lamp is supplied in several sizes—12½ c.p. 25 watts, 20 c.p. 40 watts, and 40 c.p. 80 watts. The 20 c.p. size is the most popular. It is supplied with suitably designed holophane reflectors, giving very effective lighting units.

The Tungsten Lamp.

Tungsten (or wolfram) is a metallic element, older than the tantalum, as it was discovered in 1781, and named from the Swedish "tung" (heavy) and "sten" (stone). It is not found native, but occurs in the tungstate of iron and manganese, in the mineral "wolframite," and as the calcium tungstate.

The pure metal being in the form of a powder, is a bright, steel-gray, hard, brittle, crystalline substance, heavier than tantalum (specific gravity 19.12). Its chief use in the arts has been to increase the hardness and tenacity of tool steel. Its fusing-point, according to Waidner and Burgess, is 3200° Centigrade, and it has a much higher vapor tension point than carbon, "Gem" or tantalum, which enables it to be operated at the very high efficiency of 1¼ watts per candle, or about three times the efficiency of the average carbon lamp.

The reason why tungsten has not been employed for filaments before is largely due to the fact that it was not possible to draw a wire of this material, owing to its brittle, crystalline character. The actual production of the filament has been accomplished in a roundabout way. There are several processes employed in producing this filament, which in general may be described as follows:

The metal in the form of a very fine powder or colloidal solution is made up into a paste with a suitable binder, and when brought to a proper consistence is forced through a die, forming a filament. After this is dried, the binding material is worked out of it by a suitable process, and the particles of tungsten are coalesced or sintered together by passing an electric current through them.

In another process the tungsten is deposited on the carbon filament, which by heating is converted into tungsten carbide, the carbon being then removed by heating the filament in an atmosphere of steam and hydrogen. Tungsten filaments possess properties similar to those of tantalum, high conductivity and a positive temperature coefficient, so that it is necessary to use very long, thin filaments for lamps of fairly low candle-power on 110-volt circuits. Filaments of lamps of about 20 c.p. are only .0010 inch, or :0254 mm., in diameter. A very fine hair from a lady's head measures .06 mm. in diameter, so that it would seem that 20 c.p. is about the limit for a practicable lamp in commercial voltages of 100 and over.

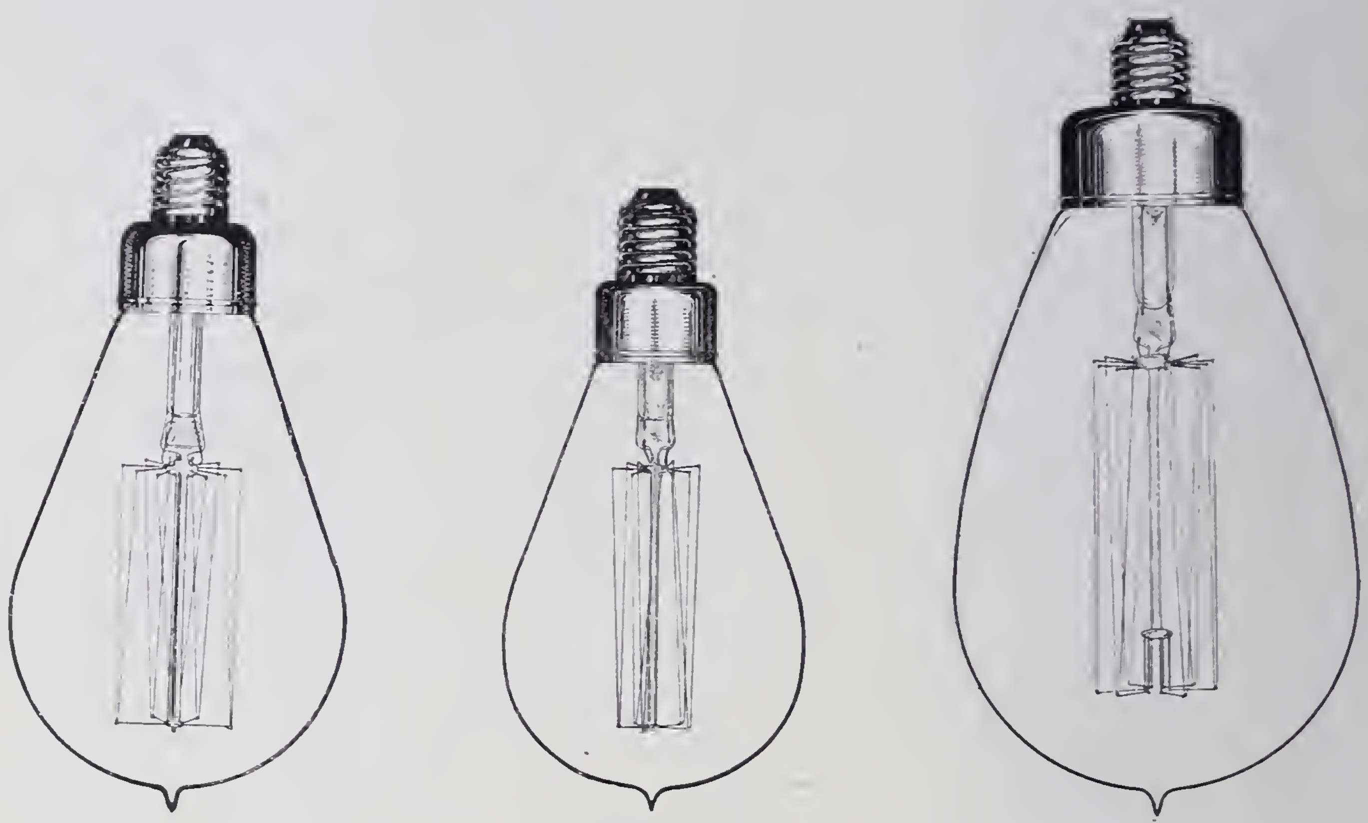

FIG. 4.—The General Electric Company's Tungsten lamps.

As in the case of tantalum, tungsten softens at incandescence, so that it is necessary to support the filament very carefully in order that it may be burned satisfactorily. The earlier lamps could not be burned in anything except a vertical pendant position, but the General Electric tungsten lamps have the filaments so anchored that they can be burned in even a horizontal position. It may be seen from the illustrations in Fig. 4 that the method of supporting the filaments is quite different from that of the tantalum lamp, as the filament, instead of being in one continuous length, is composed of a number of loops (four or five), which are connected in series with one another. The ends of each loop are fused fast to the supporting wires connecting with the base of

the lamp. As is the case with all metal filament lamps, tungsten lamps can be produced to much better advantage in voltages below 50 volts. On the same basis it would seem, where multiple voltage lamps are made, that it would be better to produce these in high candle-power sizes, as it does not appear practicable to go below the minimum candle-power value of about 20 for multiple lamps.

The chief drawback to the lamp appears to be its fragility, which renders it liable to breakage in handling and transit. To transport these lamps safely special precautions and great care in packing are required, as well as packages of considerably larger bulk than are at present necessary for ordinary lamps.

Fragility, however, has never proved an insurmountable difficulty on any lighting device, as can be seen from the case of the Welsbach mantle, which is nothing more than a fragile bit of ash. Experience shows that it is possible to transport and use tungsten lamps satisfactorily with little or no more breakage than occurs with ordinary lamps. Shipments of some seventy to eighty thousand tungsten lamps to all parts of the country have shown less than 1½ per cent. breakage.

The General Electric Company is successfully developing the tungsten lamp in a number of sizes, as shown in Fig. 4, giving a mean horizontal candle-power corresponding to 1¼ watts per candle. These lamps are supplied with special designs of holophane reflectors similar to the regular "Gem" units, thus giving a tungsten unit of double the candle-power of the present "Gem" lamps of equal wattage.

The life of the tungsten multiple lamps is very satisfactory, averaging eight hundred hours' life of practically undiminished candle-power. In this respect the lamp is unique, as it means that it can be used until it is burned out or destroyed. The tungsten lamp is also being very generally applied to street-lighting service operated in series. Tungsten lamps are particularly adapted to series lighting service by reason of the fact that low-voltage lamps are chiefly used for this class of service, and this permits a very short and stable filament to be used. There are a number of installations of tungsten series lamps, and it is only a question of time when they will replace all carbon and "Gem" filament street lamps. Recent tests of some tungsten series lamps show a life of over two thousand hours, with unchanged candle-power. The action of the constant current transformer, with increasing voltage, offsets any tendency toward decline in candle-power, and maintains the candle-power up to normal during life.

The "Gem," tantalum, and tungsten lamps all have positive temperature coefficients, which gives these lamps considerably better inherent

regulation than the ordinary carbon filament, because the candle-power energy undergoes smaller changes with change in voltage than in the carbon lamp.

The life of the tantalum lamp and tungsten lamp is less affected by increased voltage than the carbon filament, but to what extent, the lack of exact data does not enable us to say at present.

The cost of the tungsten lamp, while considerably higher than the carbon lamp of similar candle-power, is not excessive when the saving the lamp secures is considered. The 100-watt tungsten lamp, for example, will save its full additional cost at any rate above ½ cent per kilowatt hour, as compared with five 16 c.p. carbon lamps giving equal candle-power. The tungsten lamps produce a very brilliant character of light, which is of increased whiteness and brilliancy as compared with that of carbon filament lamps.

The following table gives a general comparison of the new lamps with the old. The following table shows the comparative cost of lighting by new and old lamps.

COMPARISON OF THE QUALITIES OF THE PRESENT AND NEW HIGH EFFICIENCY LAMPS.

	Ordinary Carbon Filament at 3.1 w.p.c.	"Gem" Filament at 2.5 w.p.c.	Tantalum Filament at 2 w.p.c.	Tungsten Filament at 1¼ w.p.c.
Life on D. C. Circuit.	100%	100%	175%	200%
Life on A. C. Circuit (60 cycles)........	100%	100%	75%	200%
Serviceable on any frequency down to 25 cycles..........	Satisfactory	Satisfactory	Satisfactory life on 60 cycles or less, but life decreases with increase of frequency	Satisfactory
Voltage range.......	3 to 300 volts	3 to 130 volts	3 to 250	3 to 250 volts
Divisibility into small units for 100-volt multiple service...........	Complete	Complete	Probable limit about 12 candle-power	Probable limit about 16 candle-power
Operation at any angle or in any position...............	Perfect	Perfect	Will burn in horizontal or inclined position, but not as satisfactorily as carbon	Vertical pendant position

Comparison of the Qualities of the Present and New High Efficiency Lamps.—(*Continued.*)

		Ordinary Carbon Filament at 3.1 w.p.c.	"Gem" Filament at 2.5 w.p.c.	Tantalum Filament at 2 w.p.c.	Tungsten Filament at 1¼ w.p.c.
Fragility affected by vibration.........		Will withstand vibration	Will withstand vibration	Somewhat fragile, suffers slightly from vibration	Fragile, suffers from vibration
Area of light-giving surface DL/C	At the same efficiency (3.1 w.p.c.)	2.40	2.40	5.08	4.95
	At various efficiencies shown at top of column	2.40	1.70	2.35	1.05
First cost per lamp for equal useful life..............		100%	125%	140%	170 to 200%
Steadiness of light		Perfect	Perfect	Perfect	Perfect

Color and quality of light as indicated by the efficiency at which each of the filaments would have to burn to match the light of each of the other filaments burning at the efficiency stated...........	Tungsten at 1.25 w.p.c.		
	Carbon	"Gem"	Tantalum
	1.1	1.1	1.17
	Tantalum at 2.0 w.p.c.		
	Carbon	"Gem"	Tungsten
	2.26	2.26	2.46
	"Gem" at 2.5 w.p.c.		
	Carbon	Tantalum	Tungsten
	2.5	2.2	2.02

Illumination depends as much upon the efficient use of lamps as it does upon the lamps themselves. More attention is now being paid than formerly to the engineering of lighting and illumination, and toward securing more efficient results by the proper location of lamps and accessories, thus increasing the gains from the new high efficiency lamps with scientific reflection and distribution. A proper reflector is as necessary to a lamp, to direct and satisfactorily employ the light, as a nozzle to a hose to direct the jet of water. The "Gem" and tungsten

units form a very practical method of bettering illumination, providing, as they do, a combination of lamp and scientifically designed reflector with holder so constructed as to give the lighting distribution desired, which may be used to give a uniform lighting effect on the application of a very simple law. It is hardly possible to use such combinations wrongly, and therefore results are insured which are not possible with the haphazard selection of reflector and lamps.

All previous developments of incandescent lamps have told of progress, but the introduction of the tungsten lamp means a *revolution* in lighting work. Reaching, as it does, a standard three times higher than the present incandescent lamps, the tungsten lamp surpasses all other forms of lamps in efficiency—the arc and the Nernst are all outclassed, with the possible exception of the flaming arc and some forms of vapor tube lighting. By means of its numerous and well-known advantages the incandescent lamp has maintained itself in the field in competition with other illuminants, and now that it is able to match them in efficiency, there will probably be no limit to its use except the ability of the public service corporations to supply service therefor.

In taking up illuminating problems, the natural steps are to first determine the quantity of illumination required. This varies for different conditions, but the eye adjusts itself satisfactorily over a considerable range of intensity, so that between certain minimum and maximum values the lighting is equally effective, provided it is uniform.

Uniformity of lighting, therefore, is one of the chief requisites; as where uniformity prevails the intensity can be satisfactorily reduced to a minimum. Illustration—mid-day and twilight.

The unit of illumination is the foot-candle, and the lux, which is approximately $\frac{1}{10}$ foot-candle.

One foot-candle (equal to the light of a candle 1 foot distant or to a 16 c.p. lamp 4 feet distant) is sufficient to read ordinary print by, but two foot-candles is considered the minimum for good reading or desk lighting—running up to four or five foot-candles for work having much detail.

For corridors, public places, etc., values should run from $\frac{1}{2}$ to $1\frac{1}{2}$ foot-candles. For tracing, drafting, and engraving from five to ten foot-candles are desirable.

Having determined the intensity of the illumination desired, the next step is to decide upon the illuminant and the accessories for diffusing or directing the light, and to decide as to the number and position of the units.

DISCUSSION.

Carl Hering.—The question of incandescent lighting involves two important factors—energy and cost. The curves shown this evening showed only the cost of the energy. When the cost of the lamp of to-day is three times that of the old forms of lamps, then the factor represented by the cost of the lamp increases, and it would be interesting to know how the total cost compares when the tungsten lamp is used as compared with the carbon lamp.

Mr. Willcox.—I am glad that question was asked, because that is just exactly where the tungsten qualifies. One tungsten lamp will replace five 16 candle-power lamps, giving the same c. p., 80, and save in one thousand hours' service 180 K. W. hours. The list price is $1.00 for five 16 c. p. lamps, and $1.60 for the tungsten—a list difference of 60 cents or a net difference of 48 cents. If we divide the saving, 180 K. W. hours, into this difference in cost, we can readily find out at what price per K. W. hour it will qualify, thus: 48 ÷ 180 K. W. hrs. = 0.26, or, say, $\frac{1}{4}$ cent per K. W. hour. Above this rate the tungsten lamp begins to return a saving. If we have a rate at 10 cents per K. W. hour, the one hundred and eighty hours' saving has a value of $18.00. With a 32 c. p. 40-watt tungsten costing $0.90, the saving over two 16 c. p. carbon lamps is 72 K. W. hours, and the additional list cost is 63 cents, therefore the 40-watt tungsten lamp saves its additional cost at about $\frac{6}{10}$ cent per K. W. hour and above. It is clear, therefore, that these lamps will pay their cost several times over at ordinary central station rates, and they are very economical lamps to use.

Mr. Hering.—What determines the life of a tungsten? Does it deteriorate, or does it fail completely?

Mr. Willcox.—The life performance is very good. It gives a life averaging eight hundred hours or more, with practically undimmed candle-power. The deterioration is not over 10 per cent., and, owing to the high brilliancy, the change in candle-power is not noticeable, so that the life of the lamp is actually its total life. The blackening effect in 800 hours is practically nil.

Mr. Hering.—One of the diagrams showed the price of the tantalum as 50 cents per lamp and the carbon 20 cents. Is that calculated per candle-power or per lamp? My impression was that it was per lamp, and this seems to indicate that it is per candle-power per lamp.

Mr. Willcox.—The actual price is 20 cents for the carbon 16 or 20 c. p. lamps and 50 cents for the tantalum 20 or 25 c. p. The tantalum lamp is giving for 20 per cent. less energy 25 per cent. more light, and for the same energy 50 per cent. more light as compared to the carbon lamp. For the tungsten we have a comparison of a 100-watt lamp of 80 c. p. for $1.60, as against five 16 c. p. carbon lamps, costing in all $1.00. The 80 c. p. and 75 c. p. carbon lamps sell for about 75 cents to $1.00, but this carbon lamp is now replaced by the 100 c. p. "Gem" lamp, which is listed at 80 cents. The 100-watt tungsten costs, therefore, about double the price of the carbon lamp. For the 32 c. p. 40-watt tungsten lamp costing 90 cents, two ordinary 16 c. p. carbon lamps would cost 40 cents, making this size of tungsten lamp cost nearly two and one-half times as much as the carbon, so that it is difficult to properly compare the costs on all sizes. Of course, the comparison is more favorable to tungsten as you go up to higher candle-power lamps.

Mr. Willcox, in reply to a number of inquiries, made the following statements: Some interesting experiments have been made on the color value of the tungsten lamp. At one of the large shirt factories in New York State, it was found that the matching of colors with the tungsten was very satisfactory—more so than with any other form of lamp. It approaches daylight. The "Gem" has more of the yellow light, but not so yellow as the ordinary carbon.

There is considerable speculation as to whether the tantalum lamp will hold its own, or whether it will be rendered obsolete by the tungsten. The tantalum lamp is a smaller unit and less expensive, and therefore more suitable for some installations than the tungsten. The demands for a brighter light, therefore, will result in the tantalum being used where the tungsten may not be desirable. There is an installation of 8500 tungsten and 1500 tantalum lamps in a new building in New York city, the former for the ceilings and the latter for desk lighting; one will be used as an adjunct to the other.

The tantalum lamp has had a progressive development. It would probably not be wise to judge by a trial of eight or ten lamps, or would not have been in the beginning, although it may be all right to do so now; but I never like to see any lamp judged by a test or trial of anything less than fifty or one hundred lamps. I think the tantalum is appreciated more where the entire installation is put in at once, as one is very loath to return to the carbon filament after he does that; I prefer that method rather than by trial samples.

It is very difficult to give a comparison between the tungsten and the mercury vapor lamp. The mercury vapor lamp has a very high efficiency and so has the flaming arc lamp, but, next to these, the tungsten is the most efficient lamp in use to-day.

The tungsten lamp is more practical, because it gives a light quality which is generally useful. The mercury vapor light is unsuited to domestic purposes.

PAPER NO. 1076.

THE SUBSTRUCTURE OF THE PASSYUNK BRIDGE.

HENRY H. QUIMBY.

(Active Member.)

Read September 18, [illegible].

THE bridge now in process of construction across the Schuylkill River on line of Passyunk Avenue at Point Breeze, Philadelphia, consists of twelve spans of steel superstructure on concrete masonry (Fig. 1). The eight spans of the west approach are 100 ft. each, c. to c. of bearings, of alternate continuous and cantilevered plate girder deck construction; the two spans flanking the channel are 125.4 ft. each, of riveted lattice deck trusses; the channel span is a double leaf trunnion bascule, 223 ft. between piers, with riveted trusses. The east approach span is 47 ft., the portion immediately over and close to the surface of the bank being of steel I beams incased in concrete. This portion is carried at its outer end on a 25 ft. cantilever from the lattice flank span. The total length of the bridge is thus 1323 ft. The deck will be 56 ft. wide with 36 ft. driveway paved with asphalt and two 10 ft. sidewalks paved with granolithic, except on the bascule, where both will be paved with wood.

The clear width of the channel between the fenders is 200 ft., and with the two bascule leaves raised 80 degrees—the trunnions being 16 ft. back from the fender line—this clear width will be maintained to a point 135 ft. above high-water line. The slight projection of the leaves beyond the fender line above that height will not foul with the masts of the largest vessels. The elevation of the floor of the bridge was fixed at a height that will give a clearance over mean high-water line when closed of 33 ft. under the floor beams and 35 ft. under the stringers between the floor beams—sufficient for the passage of ordinary tugs, and reducing to a minimum the necessity for opening the draw.

The west abutment and nine of the piers are of rubble concrete on wooden pile foundations. Piers 9 and 10, on either side of the channel, are also of rubble concrete, but were carried down to and founded on bed rock by pneumatic process in wooden caissons. The east abutment is merely a shallow concrete pier founded in the gravel

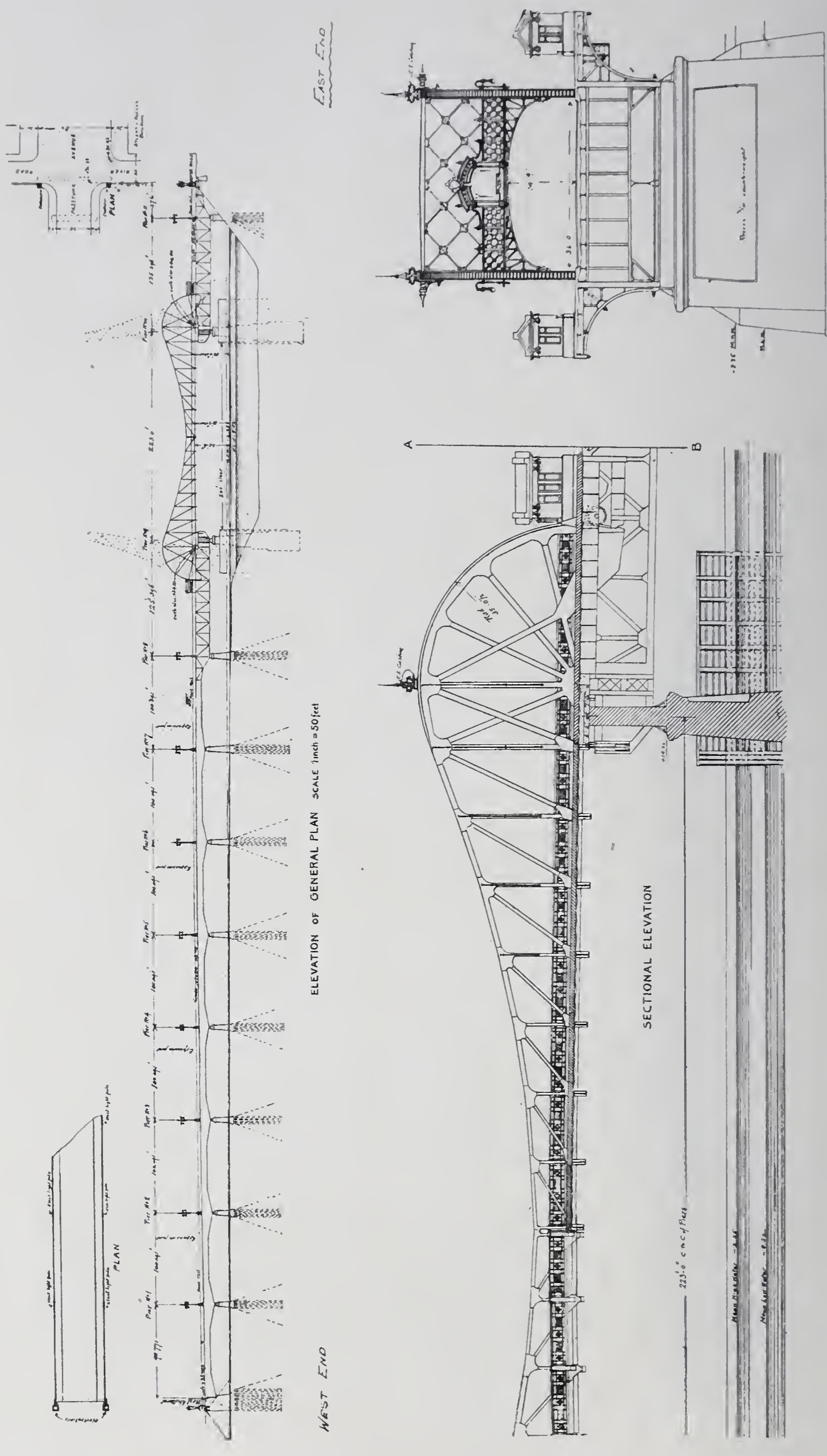

FIG. 1.—General Plan.

stratum of the east bank of the river, the slope being spanned by the superstructure, a design which was found to be more economical than that of a retaining abutment at the site of pier 11.

The two channel piers are protected by framed and braced pile fenders with independent clusters of piles (Fig. 2).

The substructure work has been completed and has been done at different times after successive appropriations by Councils and under three separate contracts. The west abutment and Piers 1, 2, 3, and 4 were constructed by David Peoples in 1903. Piers 9 and 10 were

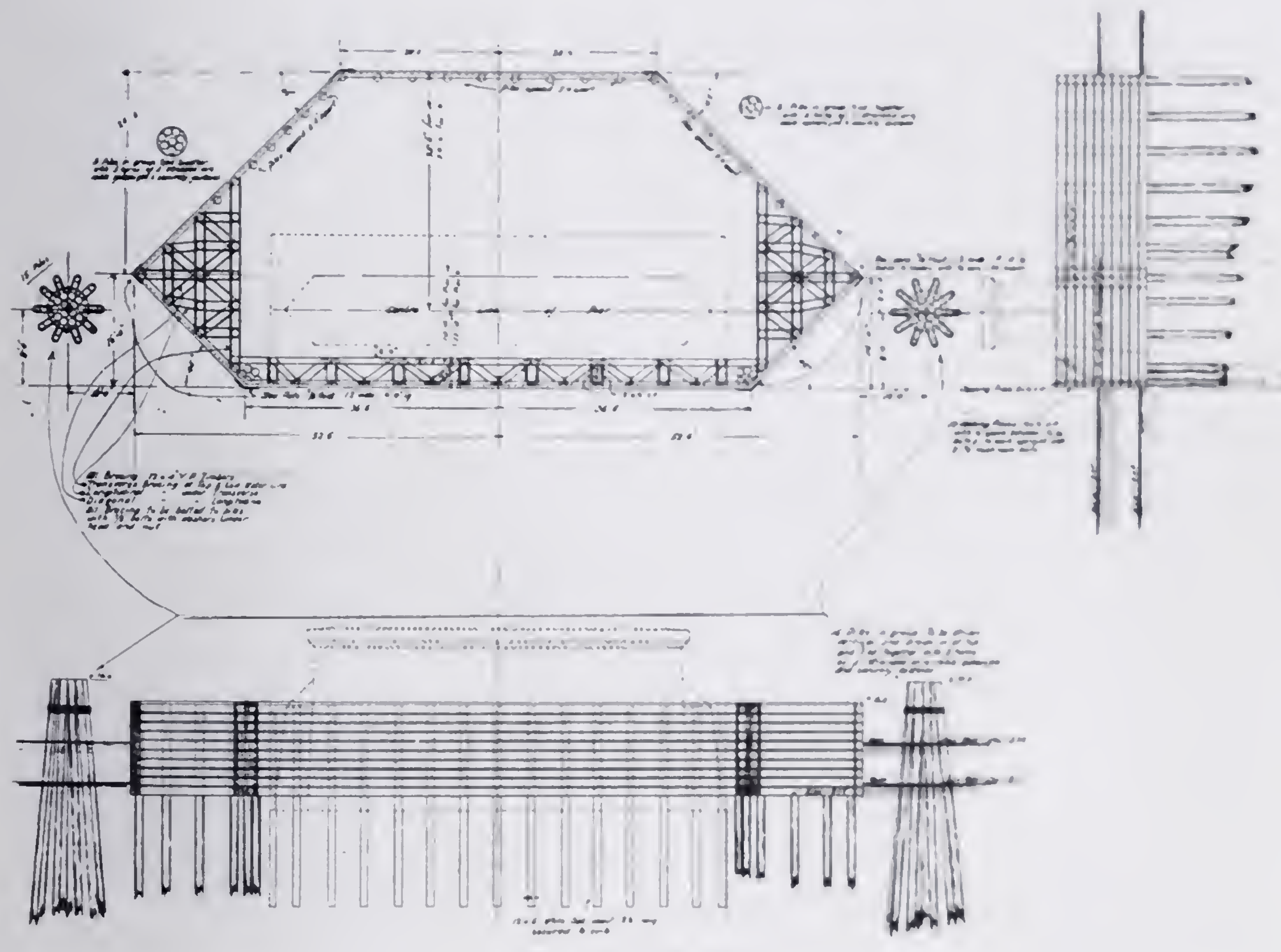

Fig. 2.—Fender.

constructed in 1908 under contract of the Filbert Paving and Construction Co., and Piers 5, 6, 7, 8, and 11 in 1909 by McGaw & Gray.

The east approach to the bridge is on high ground, the present grade of Passyunk Avenue requiring to be raised only about 4 ft. at the end of the bridge. The west approach is over low swampy land, for a considerable distance requiring a fill of about 27 ft. at the abutment. The surface is in general at about ordinary high-water line, and therefore covered by unusual high tides and freshets. The soil is a stiff marsh mud to a depth of perhaps 30 ft., and so yielding

that a bank of earth placed on it will sink into it and squash the mud up at the sides. The foundations of the west abutment and piers required, therefore, to be braced to resist horizontal forces, because the filling behind the abutment will tend to thrust the abutment forward, and if filling should be done in the future on only one side of the approach piers, a lateral thrust will be developed. This bracing was accomplished by driving spur or batter piles on all sides of each foundation.

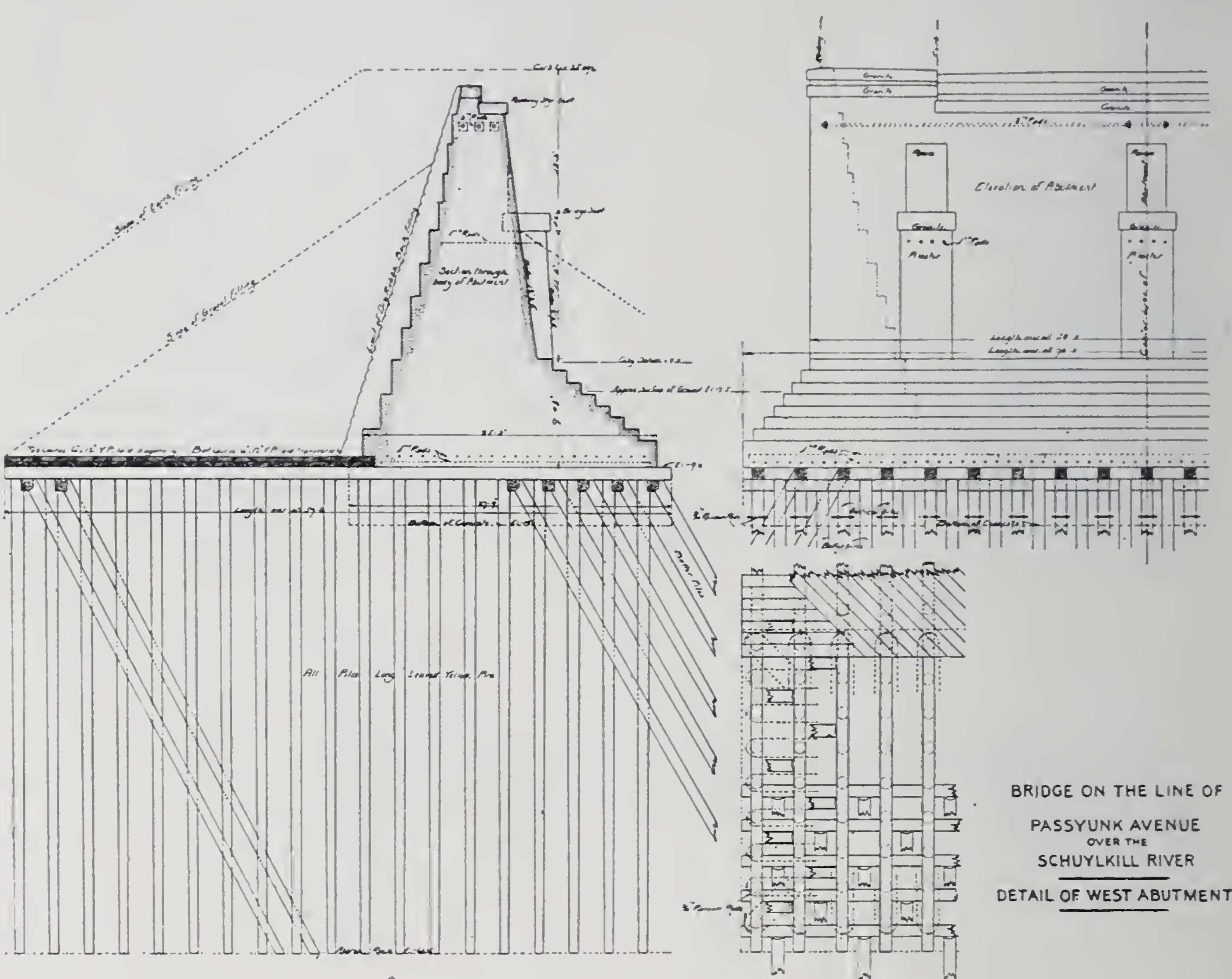

FIG. 3.—West Abutment.

The pier in the slope of the east bank—No. 11—has sufficient embedment in a clay and gravel bank to secure it firmly against lateral displacement. But it is subject to some longitudinal thrust from the bank tending to tip it toward the river. Therefore all the spur piles that could be driven in this foundation are in the one direction—riverward. To lessen the thrust the slope immediately back of the pier was excavated to the top of the foundation, and the new slope made 45 degrees and paved with mortared rip-rap to hold it.

The design of the west abutment is interesting. It was made by Mr. C. M. Mills, member of the Club, while he was in charge of the design and construction of bridges in the Bureau of Surveys. It is one of the early examples of the use of reinforced concrete. The front of the abutment is extended at the base about 9 ft. for the purpose of securing a uniform distribution of load over the piles. The center of pressure resultant from the weight of the masonry, the reaction load of the steel superstructure, and the thrust of the earth filling back of the abutment, as figured by Rankine's formula, falls at the middle of the base, and therefore gives as nearly as practicable the same vertical load to each of the plumb piles. This load is 16 tons per pile. The spur piles are not regarded as carrying vertical loads. To make the extended toe competent to safely carry the distributed load it was reinforced as an inverted cantilever with 1 in. square steel rods 12 in. c. to c., embedded 6 in. above the pile caps. Fig. 3 shows all the dimensions and the filling that was done under the contract. The three pilasters carry the seats for the three girders of the superstructure, and although constructed monolithically, they are tied into the body with steel bars. The pile foundation was extended at the back 31 ft. and covered with two layers of 6-inch yellow pine planks to constitute a platform to maintain the filling immediately back of the abutment. This filling of earth and gravel was placed as a means of securing the conditions assumed in the calculations of the stability of the abutment, because the filling of the approach will be done perhaps under other supervision in the future, and the material to be used in filling cannot yet be known.

The piles used throughout were long-leaf yellow pine, not less than 8 in. at the point and not less than 12 in. at the butt when cut off, which was done at elevation —10, mean low-water being —8.5. The plumb piles used in the foundations west of the channel were from 50 to 56 ft. long and the spur piles 68 to 72 ft. Under Pier 11, 26 ft. plumb piles and 30 ft. spur piles were driven. The spacing is from 3 ft. 9 in. to 4 ft. on centers. The plumb piles are capped with 12 in. by 12 in. yellow pine, and the spur piles generally chock against 12 in. by 12 in. stringers under the caps, though some that were found to be out of line were not strained into line, but left for mere embedment in the concrete.

All foundation piles were driven with a steam-hammer; those of the fenders were driven with the ordinary drop. The steam-hammer used in the first contract was the heaviest of the Vulcan type, weigh-

FIG. 4.—72 ft. pile ready to set.

FIG. 5.—Same pile settling under mere weight of hammer.

FIG. 6.—Same pile awaiting first blow of hammer.

ing over 9000 lbs. in all, the piston and ram being about 6000 lbs. The stroke is about 36 in., and with 60 lb. steam pressure it strikes about thirty blows per minute. The cylinder is single-acting—merely raising the piston and letting it drop of its own weight. The same form of hammer, but only two-thirds as heavy, was used in the last contract. Considerably longer time was required to drive a pile with the lighter hammer, many hundreds of blows being re-

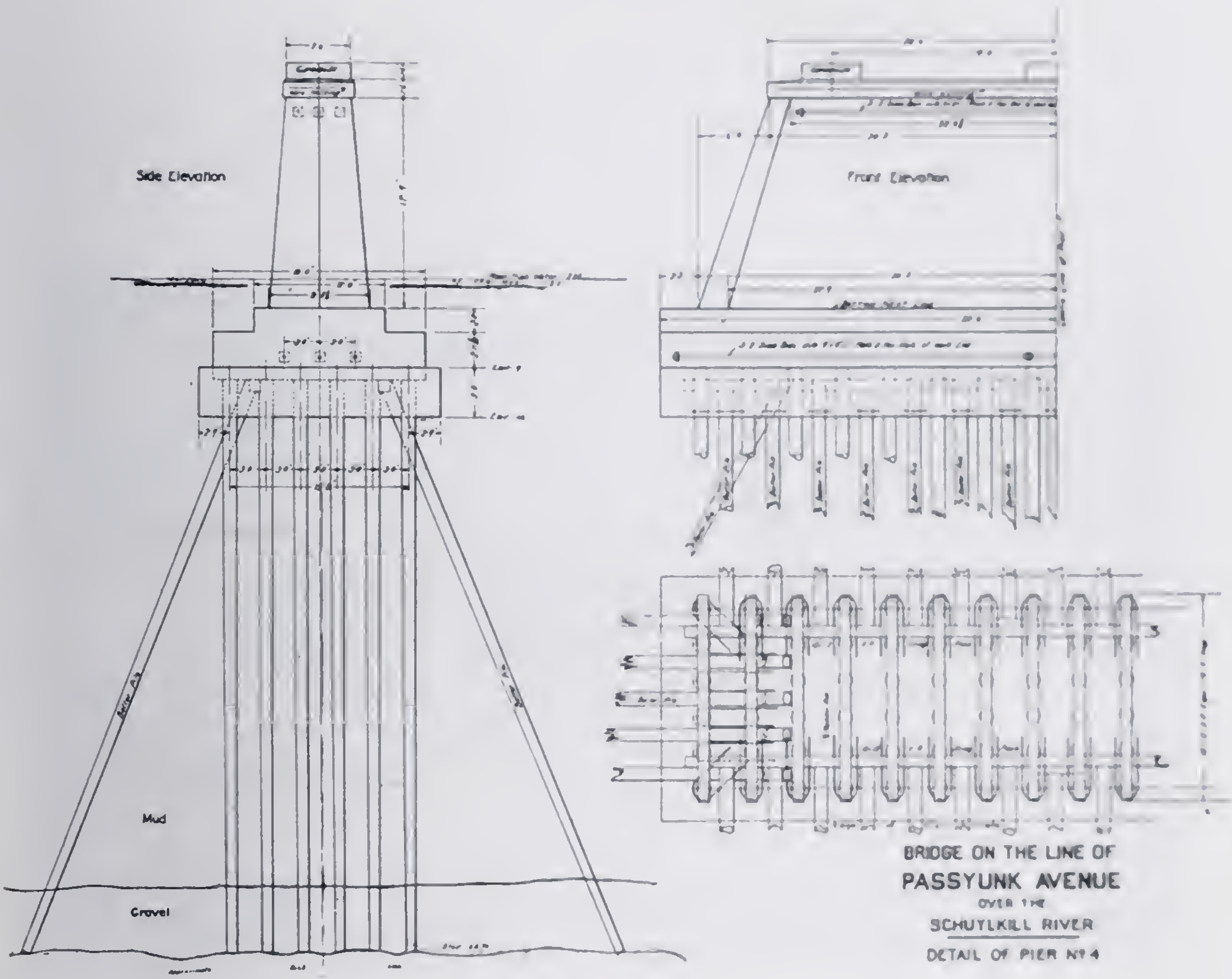

Fig. 7—Pier 4.

quired, though almost no brooming or splitting resulted. The heaviest steam-hammer is probably the most economical to use.

The slow penetration of the piles under the lighter hammer—often only one thirty-second inch per blow for several feet—suggested the possibility of the points getting broomed. Accordingly a number of the piles were shod with iron points or shoes—nineteen in all were tried—but no difference in the driving could be perceived, and it was evident that the resistance to driving was in the skin friction and not at the point.

The spur piles were intended to be inclined at an angle of 30 degrees with the vertical, but it was difficult to secure so much except at Pier 11, when the leads of the driver were suspended from a derrick boom. All others were driven by inclining the pile driver backward at an angle of 15 degrees and setting the pile at a still greater angle, driving it a short distance, then releasing it, whereby it would spring up, then moving the driver up to it and driving it some more, continuing this action until the pile was down to practical refusal.

FIG. 8.—Piles before cutting off. Shows also sheathing bulging under pressure of mud.

Figs. 4, 5, and 6 show the successive stages of placing, sinking, and beginning to drive a 72 ft. spur pile. The mud is of such a depth that the piles sank into it under their own weight and that of the hammer resting on it as much as 30 ft. below the bottom of the excavation before a blow was struck.

All piles were surrounded with concrete to a depth of 4 ft. below the cut-off. This was for the purpose of stiffening the piles which are for perhaps 30 ft. of their length in a medium that will afford

very little resistance to buckling under compression as columns, and the fixing of the top ends in concrete with the fixing of the points in 10 or 15 ft. embedment in gravel, gives to each pile two points of contra-flexure.

To maintain the integrity of the concrete and secure this fixing value for the outer piles steel bar loops were embedded in the con-

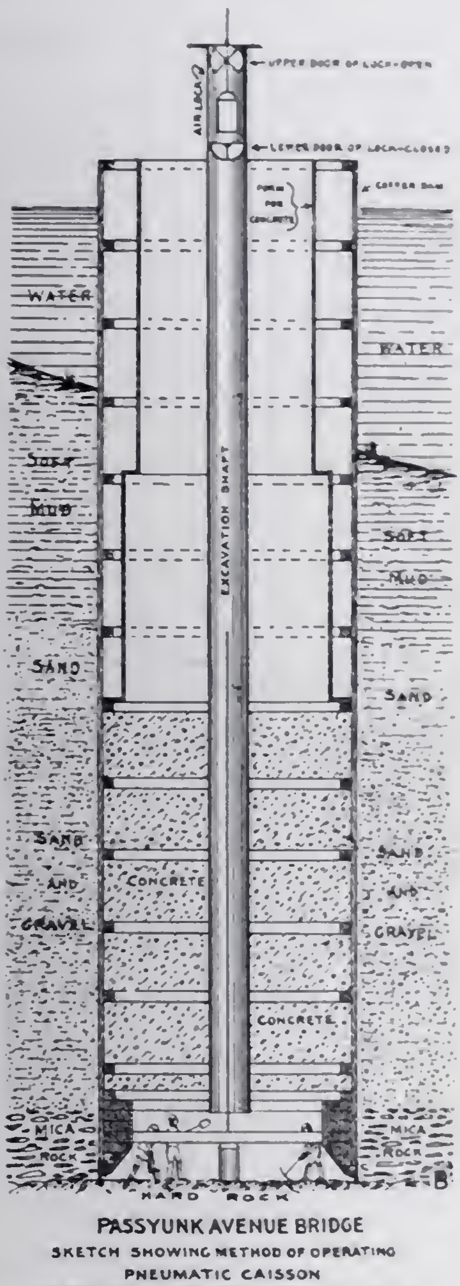

FIG. 9.—Caisson with bucket in lock.

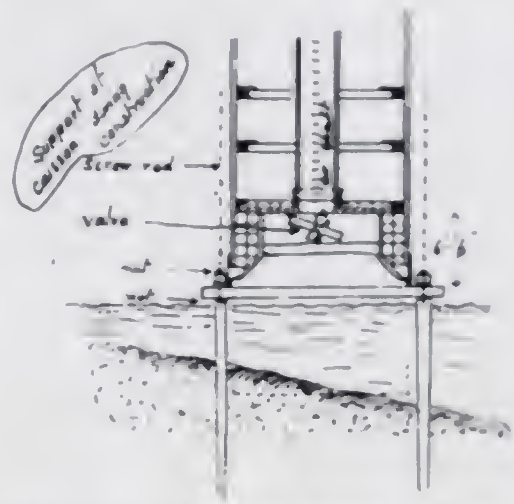

FIG. 10.—Caisson support during construction.

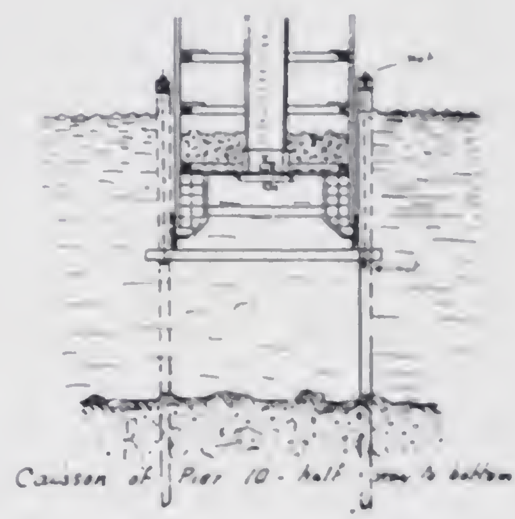

FIG. 11.—Caisson partly sunk and beginning to float.

crete around them near its lower surface extending back past the second row of piles. These should prevent any cracking of the concrete on line of the outer piles.

The piles were barked where the concrete was placed around them. To secure it to them and prevent slipping heavy spikes were driven into the wood. The mud has very little sustaining value—probably

little more than that of a fluid of about 100 lbs. weight per cubic foot with a slight head. Very little water permeated the mud, but that little mixed with it under the feet of the workmen, making a black liquid that penetrated and "killed" any concrete that might be deposited on it, and it was necessary to lay boards on the bottom, fitted between the piles, before depositing concrete.

The excavation of the mud to plan depth was done in each case before the piles were driven. After driving it was always found that the bottom of the excavation had come up among the piles—sometimes as much as 2 or 3 ft.—and had to be re-excavated. The excavations for the piers were all sheeted and very heavy waling and rangers were required, for the mud is mobile and lies very heavy against shoring. For the west abutment foundation the hole was not sheeted and the sides were sloped in. It was large enough to manœuvre the pile-driver on the bottom of the hole, but the pier holes were not, and they required heavy timbers to span them for carrying the driver.

All concrete is of the hybrid or rubble character—crushed stone concrete, 1 : 3 : 6, with large stones embedded in it by hand. All cement was Portland. The showing surfaces were made with granolithic mortar, a fine concrete, 1 : 2 : 3, placed against the forms. In the case of piers constructed in warm weather when the setting of the cement was normal, the face forms were removed on the next day after depositing and the surface scrubbed with brushes and water sufficiently to remove the film of cement and expose the sand and stone of the fine concrete. The piers of the last contract were constructed in cool weather when the setting of cement was uncertain and irregular, wherefore the face forms were permitted to remain in place until the piers were finished and the concrete was hard. The face was then bush hammered by hand. The two river piers were faced with the same granolithic mixture, but the finishing was done by sand-blasting. The effect of the three methods of surfacing will be practically the same in appearance after the action of the elements upon them for a time.

All the piers have embedded in them at bottom and at top steel rods to prevent the occurrence of vertical cracks that might arise from partial yielding of foundation or some other cause. In the earlier piers the rods were three in number at each point, 2 in. diameter, plain, with threaded ends, nuts, and washers. In the later contracts they were 1 in. square formed or twisted reinforcing bars,

in the river piers twelve in number and in the other piers nine at each point. No cracks have yet appeared in any part of the work.

The two channel piers, Nos. 9 and 10, were constructed in wooden caissons sunk by compressed air process to bed rock at elevation about —88.

The fenders around the three sides—ends and back—were constructed first and used as platforms for derricks, storage of lumber, etc. The caissons were built in position suspended over the exact pier location. Temporary piles were driven in four pairs along the front and the rear of the pier so as just to clear the caisson as it descended. On each row of piles was laid a 12 in. by 12 in. yellow pine cap parallel with the caisson. Underneath these caps and between the piles of each pair transverse 12 in. by 12 in. yellow pine beams were suspended just high enough to clear high tide, by means of 2 in. screw-rods about 16 ft. long, threaded the whole length. There were two rods to each end of each beam—sixteen rods in all. These rods were provided for the purpose of lowering the caisson into the water when ready. They passed through the caps, the upper or working nuts bearing on the caps, and carried at their lower ends iron straps under the cross-beams (Fig. 10).

The details of the caissons are shown in Fig. 9. The cutting-edge consisted of a 24 in. by ½ in. steel plate with a 6 in. by 6 in. steel angle riveted along its lower edge, back up. On the angle was placed the first layer of 12 in. by 12 in. yellow pine. On this and inside of the steel plate the siding was placed. It consisted of 6 in. thick dressed yellow pine planks in vertical position, grooved both edges for 2 in. by 3 in. spruce splines, which were driven into place from the top end of the planks of each story, and the joints were caulked on outside and inside with oakum. The walls of the caisson or working chamber were made of layers of two 12 in. by 12 in. yellow pine, drift bolted together, and strutted across with three 12 in. by 12 in. timbers dovetailed in and drift bolted. The ceiling of 3 in. yellow pine planks was supported by posts and cross-beams, without spiking, in order to be easily removable before concreting the chamber, the design being to secure a pier of continuous concrete without any interposed layer of wood. The wood ceiling was therefore only a temporary casing, serving to make the working chamber air-tight through the caulking of its joints, and to carry the first layer of concrete, which was reinforced with 1 in. rods, spaced 12 in., laid transversely. This reinforced layer furnished adequate support for the succeeding

layers, which were all bonded together with the rubble embedded stone.

Three circular well holes, 3 ft. 6 in. diameter, were framed in the ceiling, and collapsible segmental cast-iron shafts connected to them, the two end ones for hoisting out excavated material and the middle one for entrance and exit of the workmen. These shafts were carried up in story lengths to sufficient height to be above water upon first sinking, and as excavation proceeded and the caisson was lowered, additional stories were put on. The air-locks were at the tops of the shafts, but a wooden flap valve was fitted at the bottom end of each to close under the ceiling to cut off communication between the working chamber and the shaft when it became necessary to extend the shaft, which operation, of course, necessitated removing and replacing the air-lock and releasing the air-pressure in the shaft.

Two 5 in. inlet pipes for compressed air were connected through the ceiling at one corner and provided with flap valves which would check the escape of the compressed air in the chamber if an accidental break of a supply pipe should occur, as once actually did happen to the pipe laid across the river on the bottom, a sinking barge having lodged on it. A 4 in. pipe was carried up near the middle and fitted with a screw valve to reduce the air-pressure when desired or to blow out water and excavated material. A small pipe was carried up outside each shaft and provided with a valve in the working chamber and a whistle at the top end for signaling purposes. Wires for incandescent electric lights were also run into the chamber. All these pipes and wires were surrounded with the concrete of the pier and left in upon completion.

When all these connections were complete and the sides built up to a height of about 30 ft., the structure, which weighed about 200 tons, was lowered into the water by simultaneous unscrewing of the sixteen suspender rods. With all its valves closed it was a water-tight bottom and floated when sufficiently immersed. It was carried on down by depositing the concrete in it, 1 ft. of concrete sinking it about 2½ ft. (Fig. 11).

When the cutting-edge entered the river bed air was forced through the pipes into the working chamber and the water thus driven out below. Then the compressed air workmen—called "sand hogs"—went into the chamber and commenced excavation.

The spoil is sometimes of a nature that will permit of removal by means of a centrifugal pump, or even by merely letting the com-

pressed air blow it through the pipe. For such disposal the spoil must be mixed with a considerable volume of water. The water is obtained by simply keeping the air at a pressure that will permit just enough water to enter the sump into which the spoil is gathered and out of which the water is being blown. If the spoil is of a character that cannot be carried by the air and water through the pipe, it must be shoveled into buckets and hoisted out through the shafts and air-locks.

The ejectment of water and sand through a pipe standing considerably higher than a static column of water that would balance the actuating air-pressure is accomplished by permitting air to mix with the outgoing fluid—the strainer inlet of the blow-pipe is not completely submerged in the water that is being driven into it. If the surface of the water in the sump is 40 ft. below the surface of the river outside of the caisson, a pressure of air of $17\frac{1}{2}$ lbs. per sq. in. will prevent more water coming through the bed, but that pressure will drive the mixture of air, water, and sand to a height of perhaps 50 ft. to discharge over the side of the caisson. This is due to the fact that the admixture of air with the water lightens the cubic weight of the contents of the pipe to less then that of water alone.

The spoil buckets are locked into and out of the compressed air very quickly by means of spherical valve gates so shaped that the internal pressure holds them tightly shut when shut, but does not offer much resistance to the opening, which is done by a balanced lever. The upper or outer gates are notched to fit around a stuffing box through which the single hoisting cable slides when the valve is closed on it, and which remains at the same point on the cable when the valve is open and the buckets being swung around to the dump. Both lower and upper gates are edged with soft-rubber gaskets, which need to be watched and kept in order to prevent serious loss of air by blowing out when working at high pressures.

The man lock is much longer than the material lock because it is desirable and economical to have it large enough to take a whole shift of workmen at once. The valves are flat, swinging up under the cover and under the floor of the lock chamber, which is an iron cylinder 3 ft. 6 in. diameter, with two iron ladders to which the men cling during the time occupied in taking in or releasing the air-pressure. When the lock is open to the outer air the lower valve is, of course, closed, and it is held by the air-pressure below it. The passage for the men is a circular hole about 22 in. diameter. The valve is a

steel plate, perhaps ½ in. thick, weighing about 60 lbs. As the area of the opening at the rubber gasket is about 400 sq. in., less than ¼ lb. per sq. in. difference in pressure of air will hold it shut. In entering the lock, as the last man in lifts the flap the lock-tender—whose duty it is to be at the air-valve constantly—lets in the pressure from the shaft below through a 1 in. pipe, and instantly the effect is felt throughout the lock, because of the extreme homogeneity of air. The pressure at once grips the flap valve, which has not any other fastening. As soon as the pressure in the lock is the same as that in the shaft and working chamber below, the lower flap drops and the men climb down the ladder. Consideration for the safety of the men in the chamber requires that when the man lock is not in operation it shall be kept open to the shaft below to provide a quick refuge for the men in an emergency. When locking out, the air is released slowly, the outlet air-pipe being smaller than the inlet. As the increasing depth of the working requires higher air-pressure the outlet from the man lock is reduced by screwing on to it reducing fittings. At the highest pressure used on this work—38 lbs. per sq. in.—the size of the outlet was about $\frac{7}{16}$ in., and about twenty minutes time was required for the lowering of the pressure to that of the outer air. The slow reduction of pressure was for the purpose of preventing caisson disease, called "the bends."

The theory of this disease, which in its more common form causes stiffness and pain in the joints, and in its severe form causes pain in the abdomen and stops the circulation of the blood, resulting in unconsciousness and death, is that long-continued immersion in compressed air causes small bubbles of air to penetrate the tissues and the blood-vessels of the body, and if the pressure be released more quickly than the bubbles can escape, they expand in and congest the minute blood-vessels and hinder the circulation, producing pain similar to that of rheumatism.

On this work there were many cases of "bends," but no lives were lost. In the light of knowledge gained from recent operations of this nature the specifications for this work required the contractor to instal and maintain in constant readiness for use a hospital air-lock for immediate treatment of possible cases of caisson disease, and it is probable that at least one life was saved by the use of it. When a man suffers from the bends after coming out of the air, a restoration of the pressure upon him relieves him almost instantly. In the hospital lock as long a time as may be necessary can be de-

voted to the gradual reduction of the pressure. It is merely an iron cylinder about 7 ft. in diameter and 11 ft. long, divided into two small compartments, the inner having two beds in it, and both being fitted with pipes, valves and gages.

The compression of air condenses the heat in it and increases the temperature, for if the free air contains a certain number of heat units, the same number will be in the reduced volume, with proportionately higher intensity until radiated. For this reason it is

Fig. 12.—Concreting in Caisson No. 9. Shows also steel cutting edge in place for beginning construction of caisson No. 10.

necessary to refrigerate the compressed air supplied to the workings, or the temperature would be too high for the men. In the present case this was conveniently accomplished by passing the air-pipes through the water of the river, but even with that cooling the atmosphere in the caissons was always quite warm. Lowering the pressure lowers the temperature and also causes mist to form. In the air-lock as soon as the outlet valve is opened the chill of falling temperature is felt and the air becomes foggy, the moisture in it being con-

densed by the drop. If the air be permitted to escape very fast, ice can be observed forming around the edge of the outlet pipe in a few seconds.

In the work of excavation care must be exercised to dress the sides so as to keep the caisson plumb and level as it descends. Elevations are taken every day on the top at all the corners and the results given to the superintendent, who is guided by them in directing the excavation and sinking. In the early stages of its descent it can be "thrown" one way or another slightly by inclining the sides of the excavation below the cutting-edge, but after deep embedment this control is very difficult, so it is important to start the descent as nearly perfectly plumb as possible.

Care must also be taken to adjust the air-pressure to the depth of immersion, for considerations of both economy and safety. Sufficient pressure is required to keep the water down. In a porous stratum such as gravel or sand the water will stand at the elevation that hydrostatically balances the air-pressure, and it vanishes or appears in depressions of the bottom as the intensity of the pressure fluctuates with opening of valves or leaks. Excessive pressure will cause leakage and waste of air by blowing out around the edge of the caisson, or it may lift or tilt and upset the caisson, as actually happened in this city a few years ago, when a pier partly concreted was overturned and had to be blasted to pieces to be removed from the channel. The lifting power of the air under a caisson may be enormous. Every pound of pressure per square inch of surface will sustain a weight of 1 ft. in height of concrete. The pressure which the Passyunk workings reached—38 lbs. per sq. in.—will float a body of concrete above it 38 ft. deep, and therefore in sinking it becomes necessary to place concrete in sufficient body to overcome both the sustaining power of the compressed air and the skin friction of the sides. Sometimes this friction is so great that the weight of the concrete is not sufficient, and hundreds of tons of cast-iron weights or railroad rails are piled on the pier to force it down. Some foundation engineers systematically "blow" it, *i. e.*, reduce the air-pressure temporarily to withdraw the support of the air, and thus let the weight of the pier act to overcome the friction. This method was used in sinking piers 9 and 10. The last drop of No. 9 was about 3 ft. 3 ins. Bed-rock was reached and the irregularities chiseled off to obtain uniform clearance of 39 in. plumb under the cutting-edge all around. After careful inspection of every foot of the hewn sides of the excavation to make sure that no protuberances of rock should be

left to catch and jam the cutting-edge, all hands left the working chamber. Then all outlet valves were opened and the air-pressure, as indicated by a gage outside, fell gradually from 38 lbs., which was carrying 4300 tons of the pier, to 19 lbs. per sq. in., when suddenly the pier dropped 28 in., fetching up on the cushion of the suddenly recompressed air, which ran up at once to 41 lbs. per sq. in. This was due to the reduction of the volume of the air in the chamber, which was piled more than half full of the spoil from the excavation of the trench under the cutting-edge. During the trenching the spoil was not hoisted out, for fear that the opening of the bucket locks would, by jarring the pressure, start the caisson dropping before everything was ready for it and while the men were in it and exposed to the danger of the sudden increase of pressure, which might rupture their ear drums. The descending pier, which at this time was of about 7000 tons weight, was thus checked before it was all the way down, and the valves were left open until the pressure again fell sufficiently to let the pier drop the remaining 11 ins. This time it fetched up hard against the rock bottom of the trench and was permitted to remain there—82.3 ft. below city datum.

The next operation was removing the spoil and cleaning off the surface of the rock preparatory to filling the chamber with concrete. Holes were drilled 5 ft. deep in the rock to make sure that it was solid. Numerous leaks of air existed around the edge, and to stop these dry Portland cement was held in such a position at each that the escaping air carried the cement up outside the edge. The cement would adhere to the damp sides and gradually close the opening. Then concrete mixed pretty dry was tamped into the trench against and under the flat of the 6 in. edge angle and wet concrete was deposited over the whole surface of the rock. Then benches of concrete about 2 ft. high and from 2 ft. to 3 ft. wide were constructed around the sides and ends of the chamber, gradually stepping up to the ceiling, the wood ceiling being all removed. This benching was accomplished by using concrete of stiff consistence with one-man-size stone embedded, the faces of the steps being constructed with the larger stones laid up as bulkheads, using the concrete for mortar. Each tier of the benches was built to within about 2 in. of the ceiling, and after it had set the 2 in. space was tightly tamped up with a stiff mortar of cement and sand. (See Fig. 13.)

The successive tiers of benches gradually lessened the size of the working chamber until it became only a narrow gallery about 3 ft.

wide and 4 ft. deep connecting the air-shafts. This space was filled by dumping wet concrete into the material shafts clear from the air-locks, and the completeness of the filling was indicated by the flow of the viscous fluid to and up into the man shaft. The air-pressure was maintained all this time through pipes entering the shafts for the double purpose of keeping the water down and of forcing grout from the concrete into any crevices that might form by the shrinkage of the body of concrete in the chamber, and therefore every batch of concrete required to be locked into and out of the shaft, one of the "sand-hog" gang foremen going into and out of the lock with every batch to dump the bucket, alternating from full pressure to no pressure every two or three minutes, without appearing to suffer any ill effects.

When the concrete filled about 8 ft. up in the shafts the sealing was

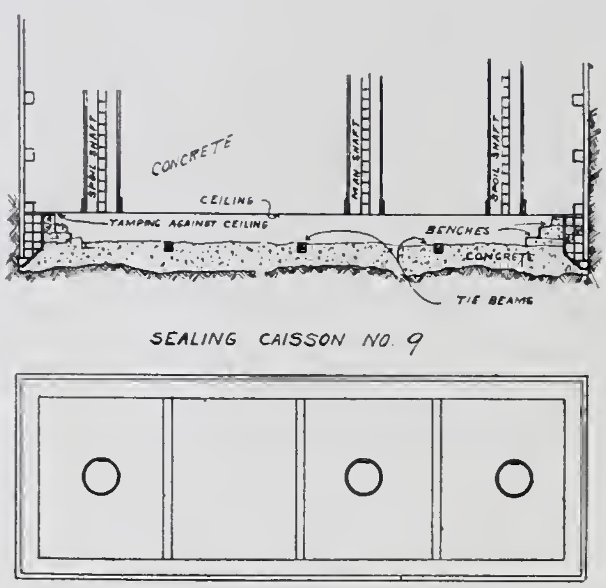

FIG. 13.—Caisson chamber partly sealed.

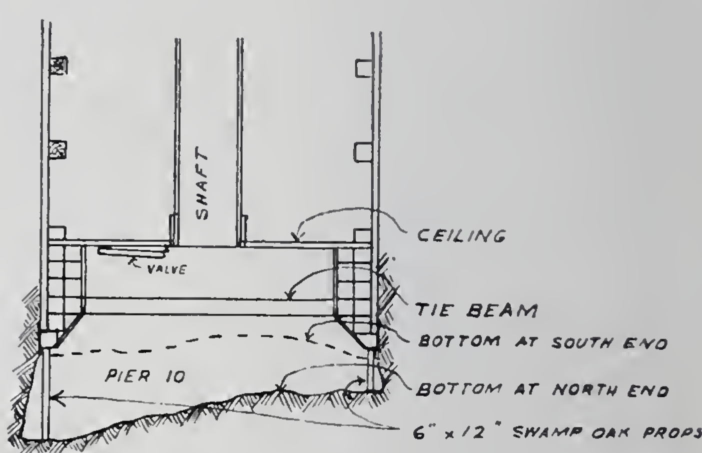

FIG. 14.—Chamber of Pier 10 ready for sealing.

regarded as complete and concreting was stopped, but the air-pressure was maintained to keep the ground water from washing in through the concrete before it could set hard. The lower lengths of the metal linings of the shafts were thus necessarily left in the pier, but all the upper lengths were of collapsible pattern, to facilitate removal before filling up the shafts. This work required the air-pressure to accomplish until all lengths were removed to above the water-line. Then the locks were removed and the water finally found its way through the concrete into the shafts, and the filling of the shafts had then to be done in the water. Automatic cylindrical dump buckets were used, so fitted that when filled and swinging on the derrick-hook the weight was carried on inside chains fast to the bottom flaps of the bucket,

but on landing the bucket two hooks on a sliding guide bar attached to the chains would drop by gravity and automatically engage the

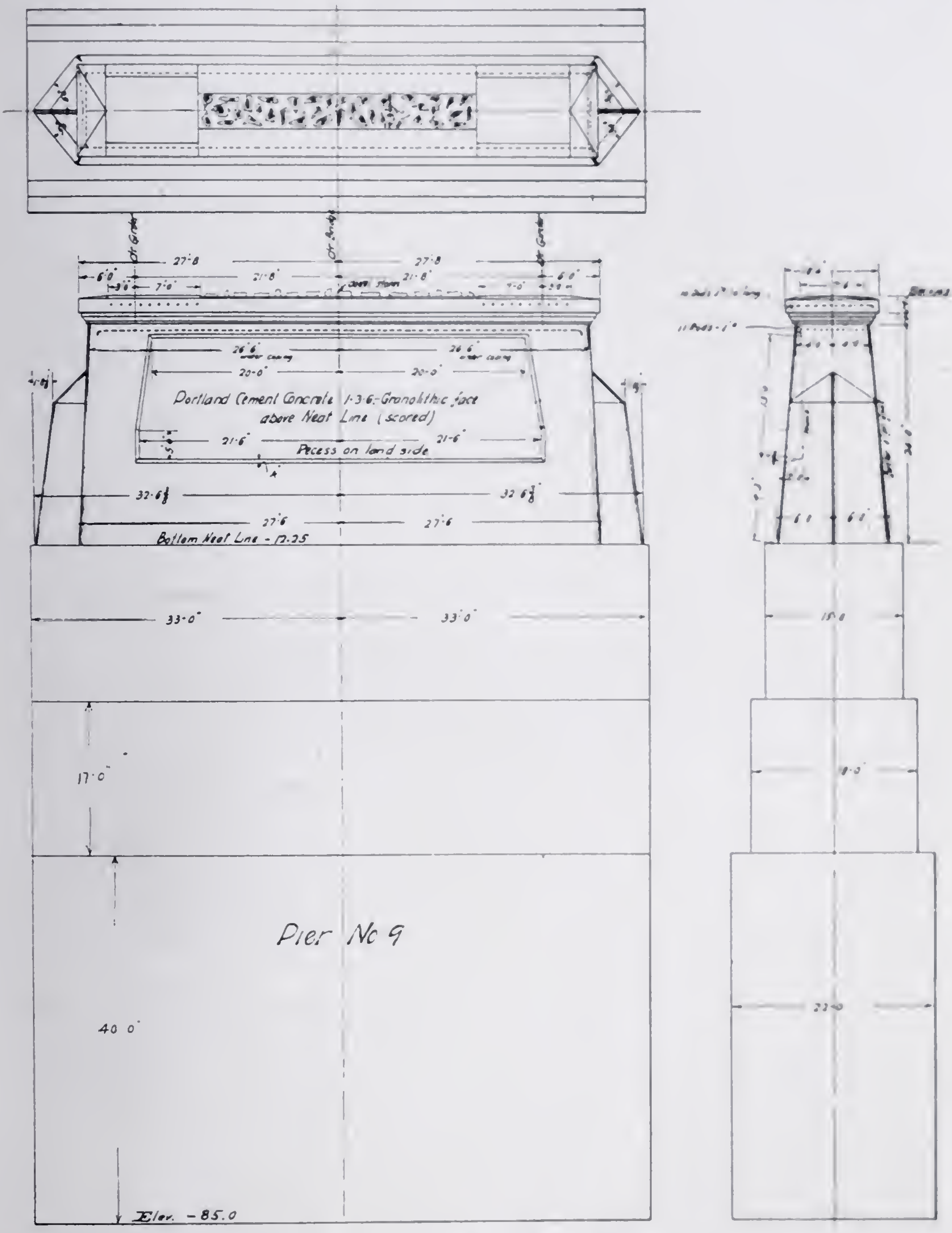

FIG. 15.—Design of river piers.

bail of the bucket. Then when the derrick-hook was raised the bucket would rise and the bottom flaps would open, letting the con-

crete flow out below, thus depositing the concrete with a minimum of agitation of the water.

The concrete plant was on a scow which was moved from one pier to the other as desired, the exigencies of sinking the caissons causing irregular work of the plant. As the pneumatic work proceeded day and night, two gangs of concreters were required, one for night work, and the shifts of inspectors were arranged so as to provide constant supervision.

The rock bottom under Pier 10 is far more irregular than that under No. 9. The southeast corner struck it first, and it was so hard that blasting with small charges—1 to 2 lbs. of dynamite—was resorted to to make a ditch there for the cutting-edge and to bench off the sloping surface into ledges for satisfactory bearing. The caisson was not sunk any lower, but remained at elevation —82.5 while excavation at the north end continued down to —87.4, the surface of the rock sloping in that direction irregularly. The north end of the pier was thus held up only by the compressed air and the skin friction, and to secure it against dropping there and tilting, through such a possible accident as loss of air-pressure before the concrete support could be placed, a number of 6 in. by 12 in. swamp oak posts were inserted under the hanging edge and wedged tightly between it and the rock surface. The excavation at this end was carried out beyond the outside of the caisson 12 in. to increase the width of base of the pier as some compensation for the increased height. (See Fig. 14.)

The material of the stratum immediately overlying the rock is a mixture of micaceous rotten rock and white clay or decomposed feldspar, and could generally be removed with shovels without picking. The stratum is perhaps 20 ft. thick and is at approximately the same elevation on both sides of the river.

The intensity of the load on the foundations of these river piers depends upon the penetrability of the bottom to water. If the water can permeate the bed and act against the under side of the concrete the weight of the pier will be very materially lightened by the flotative property of the water, every cubic foot of the pier below the surface being thus lighter by $62\frac{1}{2}$ lbs. than it will be if the water cannot act against the bottom. In the one case the maximum pressure on the foundation will be 6 tons per sq. ft. and in the other case 4 tons. This assumes a load central with the pier. In the event of wind blowing against the raised leaf of the bascule superstructure there will be an overturning moment on the pier. Although the

superstructure of the flank spans will rigidly connect each channel pier with the adjacent pile pier, we may assume that the overturning force is wholly resisted by the river pier. As the surface of a compact sand and gravel stratum is not more than 54 ft. below the point of application of the wind-force—the bottom of the steel work—the lever arm of the moment may be taken at 56 ft. Assuming a wind-pressure of 15 lbs. per sq. ft. of raised bridge floor, which is far beyond what would permit the bridge to be lifted, but might be reached by a gust striking it while up, the overturning force will be 90,000 lbs. and the center of resultant pressure will be only 9 in. from the center of the pier. Even if the embedment of the pier in the firm material that embraces it for 50 ft. of its height were to be disregarded, the center of the resultant at the rock bottom would be only 6 in. and 9 in. respectively for the full weight and the flotation assumptions, increasing the pressure at the edge of the base on the rock to 6.4 tons and 4.6 tons respectively. The maximum possible therefore is less than 100 lbs. per sq. in., which is a very low stress for even wood.

The bed of the river on the east side has no deposit of mud, as the west side has. This is probably due to the action of the current in the channel, the east side at this point being the apex of a sharp bend in the river, and such conditions are liable to cause scouring of the sandy bottom after the planting of obstructions such as the fender and the pier. No provisions have yet been made to prevent scour, either around Pier 10 or on the bank in front of Pier 11, but soundings have been made and will be made at intervals to ascertain whether scour does occur, and if it should develop the vulnerable points will be protected with rip-rap.

The total cost of the substructure work was $261,190, of which $53,060 was for the west abutment and Piers 1, 2, 3, and 4, $158,600 for Piers 9 and 10 with the fenders, and $49,530 for Piers 5, 6, 7, 8, and 11.

The contract for the superstructure has been awarded to the Strobel Steel Construction Co. of Chicago at the lump sum price of $313,000 for the work complete, including paving and lamp-posts, but no grading of approaches. The east approach is provided for in the same contract to be done under unit price items, and the estimated quantities will make it cost $8,000 additional. This east approach work, which includes street paving and repaving of sidewalks, will make the bridge accessible for use to the west abutment,

and will thus afford means of hauling material for grading the west approach from either side of the river and expedite the completion of the highway and open it to public use.

DISCUSSION.

George S. Webster.—Passyunk Avenue crosses the Schuylkill River on the apex of a sharp bend. In determining upon the design of a bridge to span the river channel at this point various preliminary studies were made and a number of types considered; also an examination at the site, with the assistance of canal boats moored in the river in the positions which would be occupied by the piers and fender. The conclusion was reached that a horizontal swing drawbridge to afford ample waterway was impracticable, owing to the serious obstruction to navigation by the fender required for the protection of the swing span. as vessels 400 feet in length pass the site, and with the completion of the contemplated deepening of the channel vessels of a greater length will be used. An additional objection to such type of bridge with a long span would be the interference with valuable wharf frontage. A design was made for a retractile drawbridge, but this was abandoned on account of the obstruction it would make in the street, at the east approach, when opened. Inspection of the treatment of analogous conditions in other cities confirmed the advisability of a bascule bridge at this locality. Accordingly the plans have been prepared and contracts entered into for a through trunnion bascule bridge. The piers and abutments have been completed and the steel work for the superstructure is being fabricated.

Charles M. Mills.—Referring to the effect of compressed air on the human physique, as alluded to by the author, and his experience in this respect, the speaker has never felt inconvenience, though spending considerable time in compressed air, the highest pressure being 32 pounds, and on one occasion passing an entire working day under 15 pounds pressure, with but one intermission. The only unpleasant effect ever felt was during the initial experience, when lack of skill in using the simple precautions suggested caused slight pain in the ears. On one occasion a cold in the head was cured after a short stay in a caisson under moderate pressure. The speaker has noticed that men of relatively slender build are those who usually escape unpleasant effects.

The care of workmen in caissons is receiving more attention than ever before. While going through the Rotherhithe Tunnel being built by compressed air under the Thames, it was learned that the contractors were obliged to maintain sufficient air-pressure to allow ventilation and keep the content of carbon dioxid below a prescribed limit; also to provide means to protect the men in emergencies due to inflow of water or other causes. Samples of air were taken periodically and tested. The sanitary features of the air do not depend wholly on the CO_2, but upon the latter in connection with other constituents usually found when CO_2 is in excess. Facilities were provided for warm baths and the regimen designed to prevent "bends" as well as for the treatment of men afflicted with them. Such precautions are recognized as in the mutual interest of owners, contractors, and workmen, and are applied with more or less thoroughness wherever pneumatic caisson work is done. They are unfortunately counteracted by the lack of care by the workmen themselves, since

the use of alcoholic liquors, to which many of them are addicted, increases the tendency to bends, and the men who do the most laborious work—that in excavating—are those who usually indulge the most.

The following comments are not made with a view to adverse criticism of the work described, since the work was in able hands, but are to be understood as applying to caisson work in general.

Referring to the drawing of the caisson as shown on the screen, which doubtless omits many details included in the working drawing, it would appear that the design was prepared with a rather close balancing of the forces which would tend to distort the caisson and those resisting distortion. In the work with which the speaker has been connected, more bracing has been used and undoubtedly has been called into service, though to what extent it is difficult to determine. If a caisson descends vertically through homogeneous material, requiring no adjustments for position or verticality, no distorting stresses are imposed. Unforeseen conditions encountered during sinking are liable to cause deviations from position or verticality, notwithstanding the information obtained by borings, and produce severe distorting stresses even allowing for the stiffening effect of considerable concrete above the roof of the working chamber. Corrective forces applied by the various methods of manipulation impose distorting stresses difficult or impossible to compute. It is evidently better to err on the side of an excess of bracing than of too little, since the cost of materials and labor for a liberal quantity is small in comparison with heavy disbursements liable to be caused by an insufficient quantity. The apparent slenderness of provision to keep these caissons in shape is counteracted by the careful provisions to regulate their downward movement, as the suspending devices contribute largely to maintaining satisfactory control.

It is further noticed that the roof of the working chamber is of but one layer of planking, supported every 12 ft. by cross-timbers. Heavy loads either upward or downward are liable to be imposed on these roofs, and the question is how much to provide for in either direction. The upward load due to the air-pressure is counteracted by the weight of the concrete, but conditions are likely to occur when considerable air-pressure may be exerted before the weight overhead is sufficient to counteract it, and, on the other hand, the weight of the first layers of concrete may not be sufficiently counteracted by the air-pressure to avoid heavy downward loading, a condition not unlikely. Again, the load on the roof may be very great before the concrete has attained sufficient depth and stiffened sufficiently to arch itself. Sluggish setting of the concrete in cold weather may cause it to remain plastic for some time after it is deposited, so that depths imposing great weight on the roof may require great strength in the latter if the air-pressure should be inadequate, due to some accidental condition. Usually transverse bracing with diagonals, forming trusses, extend between the walls above the working chamber to give stiffness to the roof and the walls as well. When caissons cover extended areas, additional trusses with heavy vertical posts are often placed below the roof of the working chamber to assist the roof, and take part of the weight overhead, since excavation below their bottom chords may be regulated as desired, the chords consisting of heavy timbers. In timber caissons the roofs frequently consist of several courses of 12 in. by 12 in. timbers, the number of course depending on the span of the roof, the method of bracing, and other details. Computation of the

stresses to be borne by the component parts of caissons cannot be exact and requires the exercise of judgment based on experience. In addition to the certain elements of duty, the uncertain elements, due to contingencies, have to be considered, and these can only be properly valued in the light of prior experience.

The assumptions made in the designing of caissons or any other structures should be scrutinized with the utmost care, since the reasoning and computations based on them may be correct and yet lead to failure if the assumptions be not correct. The uncertainties attending foundation work at the best make it necessary to be liberal and to consider every source of trouble pointed out by prior work. An illustration of the necessity for caution in this respect occurred a long time ago, in a locality remote from here, which made a deep impression on the speaker and has influenced him ever since. An open caisson was built, floated into position, and the laying of masonry begun. A question arose as to the need of additional precautions to avoid dislodgment in case of a freshet. The person in charge showed by figures that dislodgment was impossible, and a day or so after the mathematical demonstration the caisson floated some distance down-stream. The figures were indisputable, but the premises were evidently not sound.

In conclusion, I desire to draw the attention of the members of the Club to the first foundation work of note in the vicinity of Philadelphia—a remarkable achievement in view of the absence of steam power and other modern appliances. The work comprised the founding of two piers in the Schuylkill River for the "Permanent Bridge" at Market Street, as described in the "Statistical Account of the Schuylkill Permanent Bridge at Market Street, Philadelphia, Built in 1804," published under the auspices of the Philadelphia Society of Agriculture. "Permanent" distinguishes it from the floating bridges which preceded it in this locality and elsewhere along the Schuylkill. The piers are still doing service and support the present bridge on the line of Market Street, having been remodeled at their tops after the wooden structure was removed. The west pier was founded in 41 ft. of water and rests 3 ft. above the bed-rock, on gravel, since several disastrous experiences led to stopping the work at this depth to avoid the destruction of all the work accomplished. The east pier was founded on bed-rock, 23 ft. below water. Piles in the coffer-dam were driven by a "pile engine," the motive power supplied by four horses on an adjoining float. The lessons drawn by those in charge are intelligently set forth and are worthy of the attention of modern foundation builders. If the Club is not in possession of the pamphlet containing a reprint of the original account, I suggest that one be procured and placed in the library for the use of the members.

J. W. Silliman.—During the excavation for and sinking of the caissons of this work the "sand hogs" worked eight hours per day, under pressures up to 30 lbs., and six hours per day under pressures exceeding 30 lbs. per square inch. There has recently been presented to the contractors by the Union of Compressed Air Workers a new schedule calling for a maximum day of six hours, and no pressure exceeding 45 lbs. Now they evidently think that they have been working under pressures too close to the danger-line.

On account of the power plant being situated on the east side of the Schuylkill River, the compressed air used in the sinking of the caisson on the west

side was passed through a main which was laid on the river bottom, underneath the water, and there was a noticeable difference in the temperature of the air which was cooled by passing through the pipe underneath the water and that used in sinking the caisson on the east side, which passed through a pipe exposed only to the winter air.

Mr. Quimby.—The matter of lateral bracing of the caisson sides to which Mr. Mills refers is an important one to consider in a long pier. During the progress of the work described in the paper where the sides of each caisson were 66 feet long it was found that bracing was needed, and both horizontal and vertical diagonal timbers were framed in and removed or shifted as the masonry grew and itself supplied the requisite diagonal stiffness. The waling pieces or rangers were 10 inches by 10 inches and, of course, had to be spliced and could not resist much distorting pressure in a length of 66 feet.

The 3-inch plank ceiling of the working chamber might have been removed as soon as the first layer of concrete over it had hardened, for that layer was reinforced with steel rods to carry upward pressure of water in floating the caisson, or its own weight if the caisson should happen to become suspended without either water or air pressure underneath. In such work precautions are taken against every condition that can be thought of as possible to arise, and when anything happens it is likely to be suddenly. The suspender rods for these caissons were not made strong enough to carry any concrete in addition to the weight of the caisson, and therefore no concrete was placed, until the caisson was lowered into the water, and was floating, rising and falling with the tide. The only pressure, therefore, to which the ceiling planks were subjected was that of the water from below, and they were held down by cross timbers and braces above them.

Paper No. 1077.

THE TESTING OF SHEET STEEL FOR MAGNETIC CIRCUITS.

H. CLYDE SNOOK.
(Active Member.)

Read October 2, 1909.

Steel or iron for magnetic circuits is used in general in two ways, one in the form of laminated sheet, the other in the form of solid castings. This paper describes a method of testing steel in sheets for use in laminated magnetic circuits.

The ballistic method of obtaining the hysteresis curve, as developed by Prof. Rowland, although very accurate, gives only a curve of the

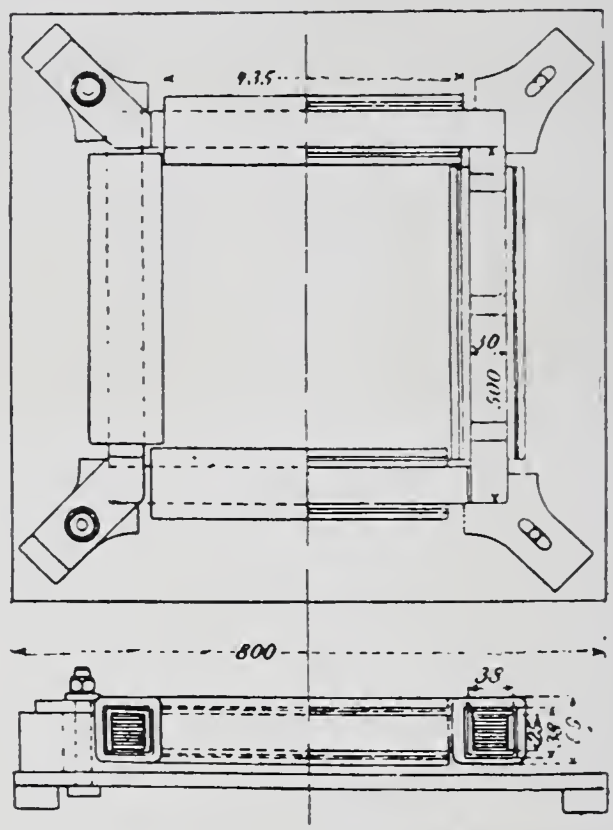

Fig. 1.—Sketch of Epstein Apparatus.

hysteresis of the iron and has nothing to do with the eddy current loss, which is of as much importance to the designer as the hysteresis itself when the iron is to be subjected to fluctuating or alternating magnetism.

The difficulty with the Rowland method is due partly to its laboriousness, since it requires much time after the apparatus is set up, and

also since much difficulty is encountered in preparing the sample. The sample, when sheet steel is tested, must be made up of ring stampings cut out of the stock sheet, and the exciting winding as well as the test winding must be wound on by hand.

After the sample is carefully prepared the ballistic method requires a large number of readings and the method is exceedingly slow. Any one who has made a test by the Rowland method feels that he has done quite a bit of work.

In order to obtain a simpler apparatus, which is more readily used, many forms of magnetic testing apparatus have been devised. Some give only the hysteresis in the iron, while others give both hysteresis and eddy current losses. Among the many forms of apparatus which have been devised may be mentioned the Ewing hysteresis tester, the

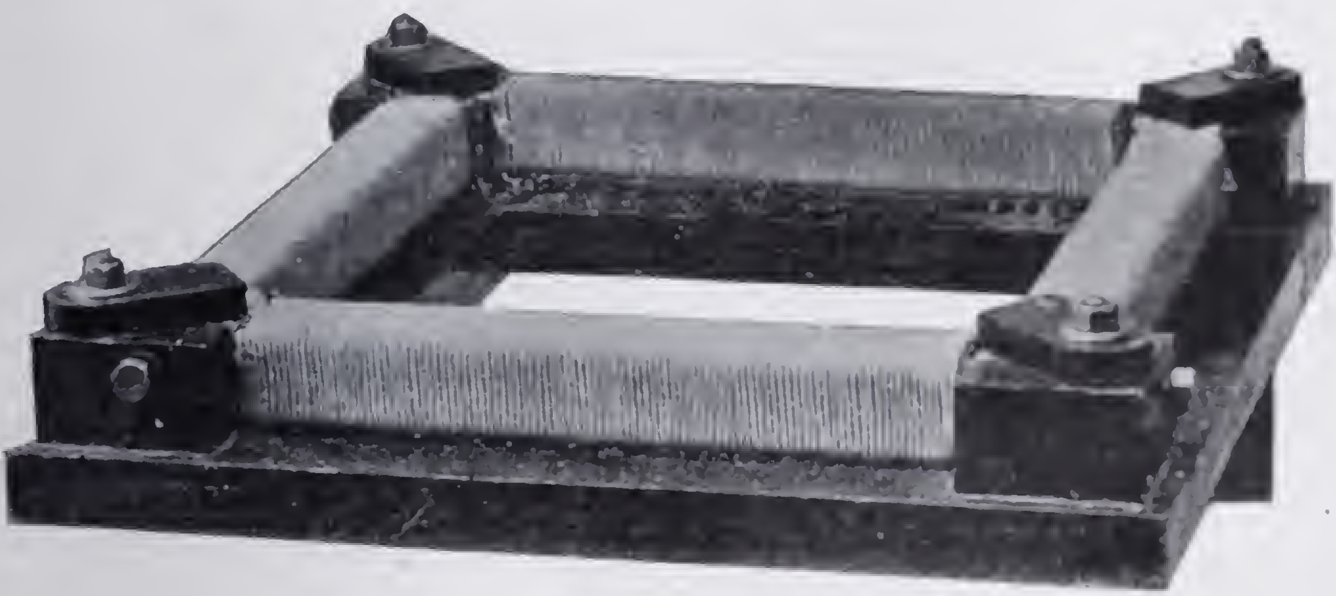

Fig. 2.—Epstein Apparatus.

Ewing magnetic bridge, the Holden apparatus, the Fischer-Hinnen apparatus, Richter's apparatus, and Mollinger's apparatus.

The two forms of apparatus last named are modifications of or developments of a type of apparatus which apparently is due to Dolivo Dobrowolsky, who seems to have been the first to develop a method of measuring the total losses in iron samples by a watt-meter method.

This general idea has been further developed by Kapp and others till it has taken a final form which was developed by Prof. Epstein, and which has the approval of the German Association of Electrical Engineers. The apparatus is known as the Epstein apparatus, and is used by the German Reichsanstalt when samples of steel or iron are sent to it for magnetic investigation.

When the author found it necessary to test magnetic sheet in order

to predetermine the dimensions of and the iron losses in transformers, which he was designing, he made an adaptation of the Epstein apparatus, which, as just noted, gives the total losses in a sample of sheet of definite dimensions. The original Epstein apparatus contained four rectangular shaped windings on the four sides of the apparatus, each winding consisting of 150 turns of copper wire, making a total of 600 turns in the exciting winding. It took a sample consisting of four cores having a length of 500 mm., a width of 30 mm., and a thickness of 30 mm.

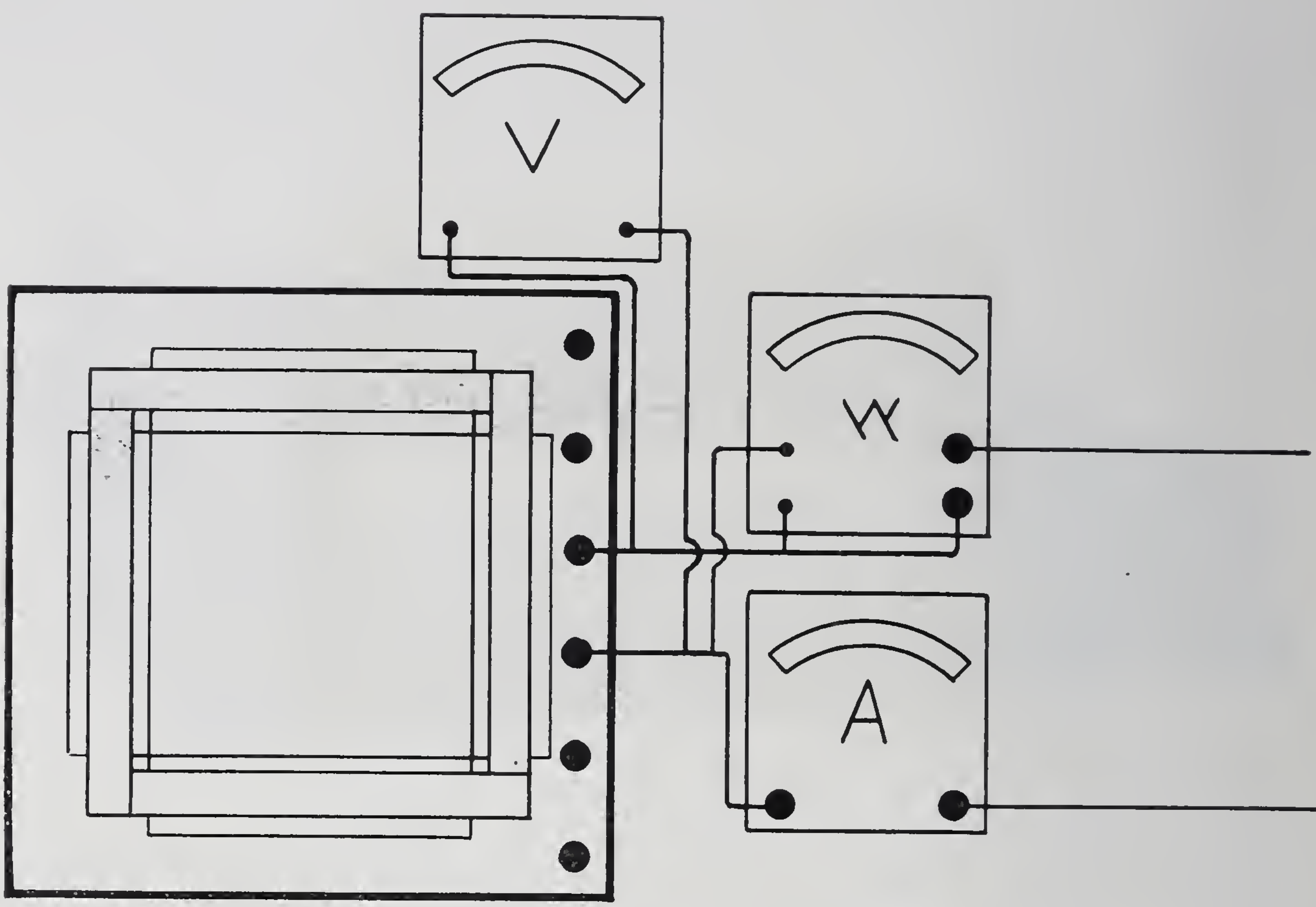

Fig. 3.—Scheme of Connections.

The general scheme involved is the use of an indicating watt-meter to measure the total energy consumption in the sample, the winding being supplied with alternating current of a definite frequency at a definite E. M. F., and the sample playing the part of a closed magnetic circuit of a transformer, while it is magnetized or excited by the winding as a primary winding.

The fundamental equation for the constant potential transformer is:

$$\phi = \frac{E\ 10^8}{4.44\ NT}$$

It is readily seen that with a constant electromotive force and un-

varying frequency the flux in the closed magnetic circuit will be inversely proportional to the number of turns in the exciting winding. Since this is the case, the flux density becomes known because of the definite dimensions of the sample and because of the definite turns which are used on the exciting winding.

The Epstein apparatus has only one set of windings, which cannot be varied, and since the author was interested in knowing the losses of the iron at different flux densities he constructed an apparatus similar to the original Epstein apparatus, but with five different variations of the turns in the exciting winding. The magnetic circuit was constructed so that it contained exactly forty cubic inches of space for the steel sheet, the individual pieces of sheet being cut 1″ × 10″.

FIG. 4.—Author's Modification of Epstein Apparatus.

This modification of the Epstein apparatus has one winding of 469 turns, which at 60 cycles and an impressed E.M.F. of 75 volts will run the iron at a flux density of 60 kilo-maxwells. The next point is of 562 turns, giving a flux density, under the same conditions, of 50 kilo-maxwells, the next point being of 703 turns and giving a flux density of 40 kilo-maxwells, the next one having 937 turns and a flux density of 30 kilo-maxwells, while the fifth point has 1406 turns and runs the iron at a flux density of 20 kilo-maxwells.

Of course, with a different impressed voltage the iron can be operated at any flux density that is desired. If 150 volts be used instead of 75 volts, the flux densities will be just twice those indicated above. It is readily seen from the fundamental formula that the apparatus is adapted to be used at any available commercial frequency, the flux

density being determined by solving the fundamental equation to which previous reference has been made.

Instead of using butt joints, as indicated in the original Epstein apparatus, lapped joints, as used in ordinary transformer practice, have been used, because the exciting current more nearly approximates the true conditions under which the iron will be used. A correction factor can be made for the change in flux density at the lapped joints, but this has not been found necessary in practice because the proportionate use of lapped joints in the transformer design itself

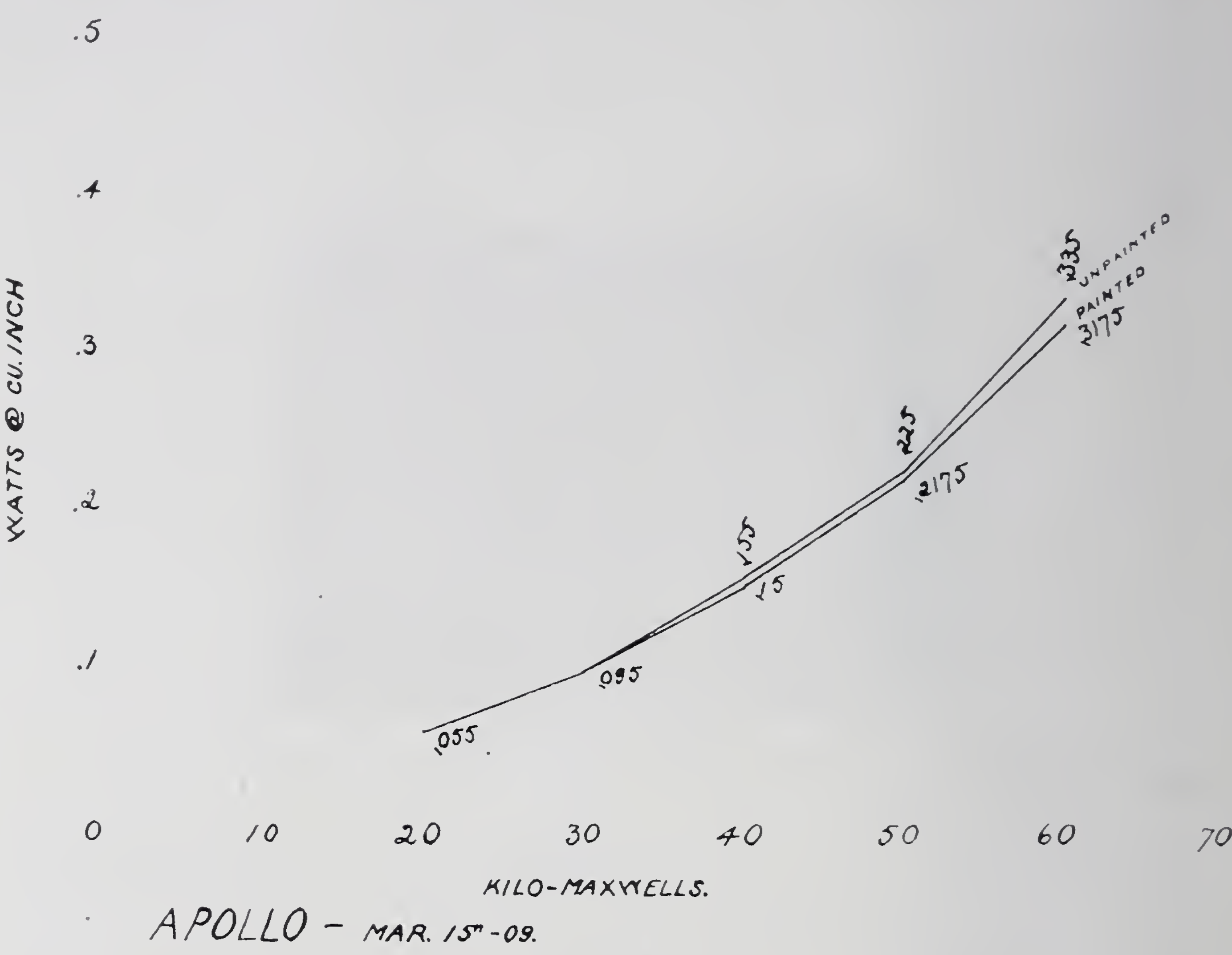

Fig. 5.

compensates for the absolute error which is made in failing to make this slight correction.

The scheme of connections which is used is an important point, and Fig. 3 gives the scheme which is preferred. It is not the one which is used by Prof. Epstein; but in the author's opinion this plan is more convenient. It will be seen that the watt-meter measures the energy consumption of the volt-meter, and its own energy consumption, in addition to the energy which is consumed in the test specimen. At a constant E. M. F. applied to the terminals of the volt-

meter, the energy consumption of the volt-meter plus the energy consumption of the watt-meter will be constant within the range of the tests; since the increased energy consumption in the current coil of the watt-meter, due to the additional current which will flow when the Epstein apparatus is added to the load, is negligible.

The author prefers to plot his curves with the energy consumption per cubic inch at definite flux densities rather than the watt consumption per pound, since it is more convenient for use in transformer design. If it were to be preferred, the curves could be plotted the other way, since the weight of the sample is obtained without difficulty. Fig. 5 gives a characteristic curve which is obtained by plotting the results obtained with this apparatus.

If one is interested in a separation of the hysteresis from the eddy current losses, this may be accomplished by running a series of tests with this apparatus at different frequencies. If the impressed E.M.F. and the turns be changed so that the flux density remains constant, the solution of the following equations will enable the operator to separate the losses:

$$W_1 = E\,n_1^2 + H\,n_1$$
$$W_2 = E\,n_2^2 + H\,n_2$$

in which equation—

$E\,n^2$ = eddy current watts.
$H\,n$ = hysteresis watts.
n_1 and n_2 = two different frequencies.

It is advisable to work out the results from more than just two different frequencies in order to increase the accuracy of the results.

DISCUSSION.

Carl Hering.—When the same piece of iron is tested a number of times, how nearly would the tests agree with one another when carried out by this method?

Mr. Snook.—It depends upon the temperature of the sample. When the conditions are the same, the reading is the same. If you vary the excitation, *i. e.*, if you use the impressed E. M. F. from one machine at one time, and another one at another time, there is a different loss obtained, because different machines give out different harmonics, and the harmonics very appreciably modify the energy consumption. Also the wave form, if it be considered apart from harmonics, whether a peaked or flat top wave form. Of course, peaked or a flat top wave forms are considered to have harmonics in them; but the wave form of the E. M. F. and the temperature of the iron are the two things which in my experience have influenced most the energy consumption in the iron.

A minor thing which affects it appears to be the tightness with which the

samples are clamped, giving an increase or decrease of the eddy loss by a decrease or an increase of the electric circuit between sheets.

Mr. Hering.—I would like to get some idea of how accurately such tests would agree. Suppose I had three samples and you tested them; if I then interchanged them and gave them back to you, could you identify them?

Mr. Snook.—Absolutely—without question.

Mr. Hering.—Suppose some one else measured the same sample with other methods and instruments, how nearly would they be likely to agree with yours, supposing, of course, that the other method was also a good and approved one and was carried out as perfectly as it could be? Could the Bureau of Standards at Washington adopt some such method and get absolute results for standardizing samples to be sold for use as secondary standards for making comparative tests with other samples of iron?

Mr. Snook.—It is my understanding that the National Bureau at Washington has an Epstein apparatus and uses it. Whether they have modified it so as to operate the iron at different flux densities, I do not know. The chairman of the German Reichsanstalt certifies no iron except by the Epstein method.

I really feel like apologizing to the Club for presenting this paper, because the only new thing in it is the change in the construction of the Epstein apparatus whereby it is modified so that I can test iron at different flux densities. By this method, however, I can predetermine the energy loss in transformers to my entire satisfaction.

Mr. Hering.—Do I understand that the flux density is not varied in the tests made by the Reichsanstalt?

Mr. Snook.—They use it approximately at 70 kilomaxwells; 70,000 lines per square inch, and no other flux density is used.

Chas. E. Bonine.—Mr. Snook has selected a line of testing in which it is very easy to measure hysteresis and eddy current losses and apply these measurements to practical designing. I have had no experience in using steel in transformers, but when using steel in armatures unfortunately you have to deal with the workman, and although you may calculate the eddy current and hysteresis losses from results of samples of the steel, when the armature is completed you will find that the eddy current loss may be many times that expected. The workman in assembling the laminations may, owing to slight irregularities in punching, drift the slots and burr the plates to such an extent that many of the plates are short-circuited, and the eddy current loss in consequence will reach a very high value.

I know of one particular case where a large motor, when tested at light load, developed a temperature high enough to scorch the armature insulation. The heat was due to eddy current loss induced by excessive drifting. But by careful manipulation in the shop, or where the laminations are punched so that good alignment of slots is obtained without drifting or excessive filing, the eddy current losses will be fairly close to calculations based on samples. However, this loss will always be higher than calculated. Again, the density throughout the iron is not uniform, and it is practically impossible to figure what the increased loss will be from this cause alone. I should like to know whether somewhat similar troubles are experienced in large transformers.

Mr. Snook.—Yes. The total losses in the iron will always be just a little

higher than they ought to be, because the flux density in the turns of the magnetic circuit will be high, and also because of the same troubles which the designer of the motor has, but to a much lesser degree. The clamping up of the steel sheets tightly together will, of course, increase the eddy current losses.

Mr. Bonine.—I do not know the ratio between the losses in transformers, but in armatures the eddy current loss may be as high as ten times the hysteresis loss. The new silicon steel, on account of the hardness of the scale on its surface, cannot often be used in direct current armatures. The laminations of such armatures (particularly the smaller sizes) are punched at one blow, and the dies for producing them are complicated and costly. With low-carbon, well-annealed steel, free from scale, 50,000 punchings between grindings is not unusual, whereas with silicon steel only a fraction of such number could be obtained.

M. E. Leeds.—I would like to ask Mr. Snook if he has applied the knowledge he has gained in regard to transformers to designing instrument transformers so as to make transformers that are very constant for their performances?

Mr. Snook.—I made one for Mr. Hering not long ago which he has not yet tried out, but I think it will be fairly good. I have not made any other instrument transformers than this one which I made for Mr. Hering, so my experience is exceedingly limited. The temptation in the way of one that designs instrument transformers to-day, particularly with the new steel available, is to run the flux density up high, so that the exciting current will be high. The hysteresis loss of the steel is very low, and it is a temptation with a small hysteresis loss to run the flux density up higher than one ought to, making the exciting current high; that is one of the problems of transformer design to-day.

Paper No. 1078.

THE MULBERRY STREET VIADUCT, HARRISBURG, PA.

JOHN E. ALLEN AND BENJ. G. LOVE.
(Active Members.)

Read October 16, 1909.

The Mulberry Street Viaduct is a reinforced concrete highway structure of the rib arch type. It consists of a main bridge 1841 feet long and 60 feet maximum height, spanning Paxton Creek Valley from the center of Harrisburg to the suburb of Allison Hill, and crosses Tenth Street, Cameron Street, Paxton Creek, and twenty-seven tracks of the Pennsylvania Railroad and Philadelphia and Reading Railway. At the western end, 600 feet is on a 12-degree curve and the remainder on a tangent. An inclined approach, 600 feet in length, from Cameron Street, connects with the main bridge at about the middle of its length. The bridge replaces a steel structure built in 1891 and considered unsafe for the increased traffic of to-day.

The bridge was designed and the construction supervised by Mr. James H. Fuertes, Consulting Engineer, of New York city, and is believed to be the most advanced development of the rib arch in this country and the first attempt to apply this type to a continuous structure of such magnitude.

The main bridge has a roadway 28 feet wide and two sidewalks each 8 feet wide, and the Cameron Street approach has a roadway 21 feet wide and one sidewalk 6 feet wide. Supporting the deck are ten segmental arches of 100 feet span and fourteen arches of spans varying from 40 feet to 96 feet. The main bridge has grades of 1 and 3 per cent. and the Cameron Street approach grade is almost 7 per cent. The design was complicated by the lack of headroom over the railroad tracks and by the necessity for placing all piers on the curved portion of the bridge parallel with the tracks and oblique to the superstructure, causing a number of skew spans. The spans of the main bridge, 100 feet in length, are carried on arched piers about 40 feet in height from the ground to the skewbacks.

Near the center of the bridge is a massive abutment pier designed to take the unbalanced thrust of the Cameron Street approach spans

FIG. 1.—Mulberry Street Viaduct.

and serve as a landing for this approach. There are three abutments with retaining walls and earth fills, the east abutment, on Allison Hill, about 75 feet long, the west abutment, 150 feet long, and the Cameron Street abutment, 100 feet in length.

The main bridge spans consist of four reinforced concrete arch ribs, without openings, and serve also as spandrel walls for the deck support. The deck consists of a continuous slab of reinforced concrete supported on transverse floor beams which are carried by the spandrel walls. The slab cantilevers beyond the outside ribs and is strengthened by ornamental brackets. The roadway is paved with asphalt and the sidewalks are granolithic. The railings are of wrought-iron pipe supported by concrete posts. The posts over each pier are enlarged to form a base for the lamp-posts, which are also of concrete. Drainage was provided by grate inlets over each pier with outlets of cast-iron pipe carried down through the piers and discharging at their base. The Cameron Street approach is similar in design to the main bridge except that the deck is carried by three arch ribs instead of four.

A continuous line of rein-

forcing bars was placed in each rib along the entire length of the bridge immediately below the level of the deck, and this reinforcement was heavy enough over each pier to support the two adjacent half spans as cantilevers. After the bridge was completed from abutment to abutment, these bars were cut over each pier, which allowed each span to become an arch. The specifications required that arch construction should be carried on without subjecting the piers to an unbalanced thrust.

The bridge was designed for a uniform live load of 200 lbs. to the square foot over the entire roadway, 150 lbs. per square foot over the sidewalk area, and 40-ton electric cars on two tracks. The floor slabs are proportioned for a local concentration of 1000 lbs. per square foot and the floor beams provide for maximum shears of 24,000 lbs. The concrete is proportioned for maximum stresses of 500 lbs. per square inch where reinforced and 300 lbs. per square inch where not reinforced. The reinforcement was stressed to 16,000 lbs. per square inch. All foundations were carried to hard rock.

Bids for the construction were received July 5, 1907, and the contract was awarded to McCormick & Co., of Philadelphia, on July 30, 1907, at unit prices for the various materials and operations, reaching an approximate total of $262,000. The quantities included 17,000 cubic yards of excavation, 21,000 cubic yards of concrete, 600 tons of steel bars, 2000 linear feet of cast-iron pipe, 5000 linear feet of pipe railing, 5000 linear feet of electric duct, 7000 square yards of asphalt paving, and 44,000 square feet of surface dressing. Allen & Love, of Philadelphia, were retained by the contractors as consulting engineers.

Field work was started by the demolition of the existing bridge. The Etter Erecting Co., of Philadelphia, was awarded the subcontract for this work and began operations on August 6, 1907. The old bridge consisted of 100-foot spans of pin-connected deck trusses and 70-foot spans of through Pratt trusses with cast-iron compression members. The flooring was of timber. The work was accomplished by a two-boom traveler on the bridge deck, the structure being supported by light timber bents at the panel points. The material removed amounted to approximately 350 tons of structural steel and 240,000 feet B.M. of lumber. This work was somewhat delayed on account of the difficulty of obtaining a right of way over the railroads and making satisfactory arrangements for the protection of railroad traffic, but the operation was successfully concluded by October 15, 1907.

Office and shop buildings were placed under construction August

3, 1907, and the working plant assembled. The buildings consisted of a main office, engineer's office, blacksmith shop, a fully equipped sawmill, a cement storehouse of 2000 barrels capacity, a stable, and three buildings for the storage of small tools and supplies. A large platform for laying out full size form details and a well stocked lumber yard completed the layout. The working plant comprised six derricks and hoisting engines, five concrete mixers, four 6-inch steam pumps, four portable boilers, an air-compressing plant, a 10-ton road roller, and the large variety of small tools necessary for such a construction. The maximum force employed on the work was 200 men and an average force of 100 men was carried throughout.

Construction of the new bridge was started on the foundation excavation for the abutment of the Cameron Street approach, September 1, 1907. Excavation was through fill, clay, and water-bearing gravel to rock at depths varying from 20 to 30 feet. Water was found at a depth of 10 feet in all excavations and in such quantities that a 6-inch pump could not maintain a condition fit for placing concrete. Outside sumps were tried and the sheathing calked without much effect, and it was found necessary to enlarge the excavations and build watertight forms, which were practically cofferdams, inside the sheathing. With this, it required pumping night and day to control the water until concrete was placed above the water-line.

This work on the eastern section of the bridge was simple in comparison with that on the western section. Here, in addition to the water, was found a sliding soil, which required heavy shoring to prevent the railroad tracks from caving into the excavation. The volume of railroad traffic was another obstacle, and all tracks were required to be kept open, although the clearance between the cars and the work was not sufficient for standing room for a workman. The excavated material was raised by a derrick mounted on a flat car and loaded directly on cars for removal.

The foundation concrete was a 1 : 3 : 6 mixture, the sand used being dredged from the Susquehanna River near Harrisburg. The use of this sand was discontinued above the neat line on account of the quantity of coal dirt which it contained, samples yielding as much as 30 per cent. at times. For the remainder of the work, sand was procured from the west branch of the Susquehanna River about 40 miles above Harrisburg, and proved very satisfactory.

The pier foundations, from 6 inches below grade to rock, consist of two shafts 8 x 8½ feet in cross-section and 31 feet apart on centers.

They are enlarged at grade to form pedestal bases $8\frac{1}{2} \times 11$ feet and 4 feet high. Above these bases the cross-section is $9\frac{1}{2} \times 6\frac{1}{2}$ feet, ornamented with taper pilasters and a cornice. The shafts are connected above grade by a semicircular arch of 21-foot span forming an ornamental portal. Supported on these shafts is a girder 12 feet deep, 7 feet wide, and 45 feet long, on which the arch ribs are seated. This girder contains about 133 cubic yards of $1 : 2\frac{1}{2} : 4\frac{1}{2}$ concrete. It was

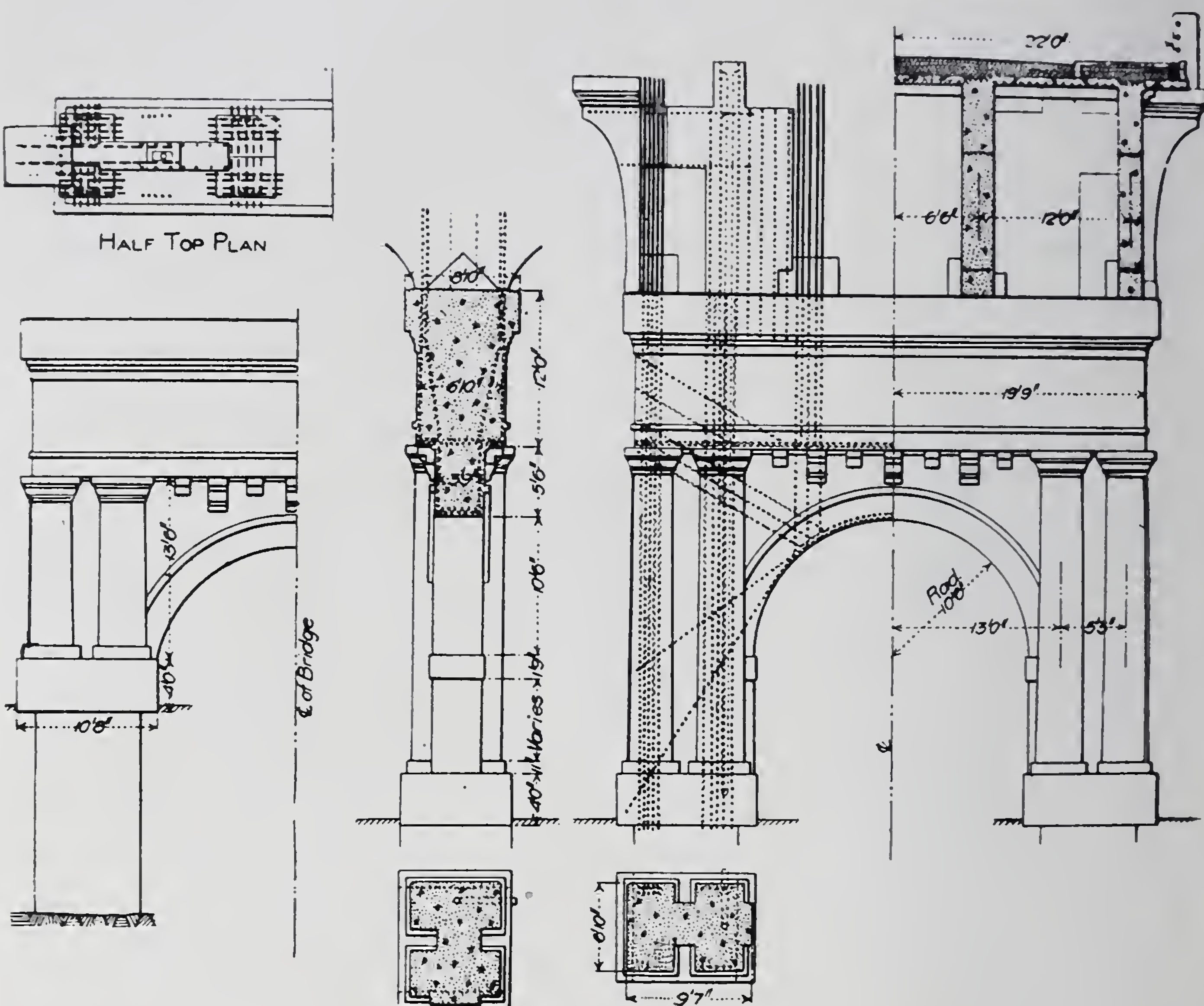

FIG. 2.—Main Bridge Piers.

required that it should be molded monolithic, which required about sixteen hours of continuous work. The reinforcement consists of 31 twisted bars 1 inch square along the bottom. The triangular skewbacks 5 feet 6 inches on the base, 2 feet 9 inches in height, and 4 feet 6 inches long, were molded on top of and with the girder. A mat of steel bars was placed in their upper surface. Above the girder and extending to the under side of the bridge deck, curtain walls 2 feet thick connected the outer pair of arch ribs and acted as sway braces.

Outside of the ribs from the girder to the bridge deck, large projecting brackets were placed to conceal the expansion joint between the ribs and form a base for the lamp-posts. Reinforcing bars, continuous from rock to bridge deck, and with a combined area of 15 square inches, were placed in each side of both shafts and provided for a bending moment caused by a possible unbalanced load of 20 tons during arch construction. All pier concrete above the neat line was a 1 : 2½ : 4½ mixture, and large stones were allowed in the girders.

The piers required very intricate form work and the necessity for monolithic construction increased the strain on them. Sectional forms were used and each set was shifted three times. About 15,000 feet B. M. were required for a pier and an average force of 35 carpenters were employed throughout the work. The forms were wired together through the concrete and the braces were anchored to the concrete as it was placed by bolts with the nut end in. Soap was used to lubricate the forms. Horizontal joints in the concrete were made by placing large stones projecting above the surface, and before work was resumed the surface was washed and flushed with cement grout. The concrete was mixed wet and thoroughly tamped and spaded. Bottom dump buckets were used in placing it.

The finished piers are very rich and imposing in appearance, while retaining the lightness in keeping with the entire design. They contain an average of 400 cubic yards of concrete each, and it took about three weeks time to construct one. The entire surface was hammer-dressed. The work was handled by guy derricks with 90-foot masts and 85-foot booms, so located that they controlled the work on two piers each.

On the western section of the bridge the portal effect was not used on account of the low piers, but the general construction was similar throughout. Here the ground was not firm enough to support the girder forms, and they were built within timber trusses, with a clear span of 23 feet, supported directly on the pier foundations. The flooring was suspended below the truss by ¾-inch bolts, and the construction being monolithic made it necessary to camber these trusses to overcome the deflection. The piers contained about 324 cubic yards of concrete.

Owing to the lack of clearance through the railroad yards, it was necessary to have the pier forms self-supporting. No inclined braces or shores could be used and the forms were built in a crib work of heavy timbers securely bolted together. There being no ground space

for a concrete plant, recourse was had to a traveling plant. The mixer was placed between the tracks at the end of the pier and the derrick was mounted on a flat car, coupled in a train with supply cars of cement, sand, and stone and moved in on a track adjacent to the work. Whenever the track occupied was needed for travel, the entire train was backed onto a siding and returned when the way was clear. Fairly rapid progress was made considering the annoying but unavoidable delays and conditions, concrete being placed at an average rate of 80 cubic yards per day. Piers through the railroad yards contained about 350 cubic yards of 1 : 2½ : 4½ concrete and were 20 feet high, 8 feet wide, and 51 feet long.

The east abutment is built on the rock face of Allison Hill. The

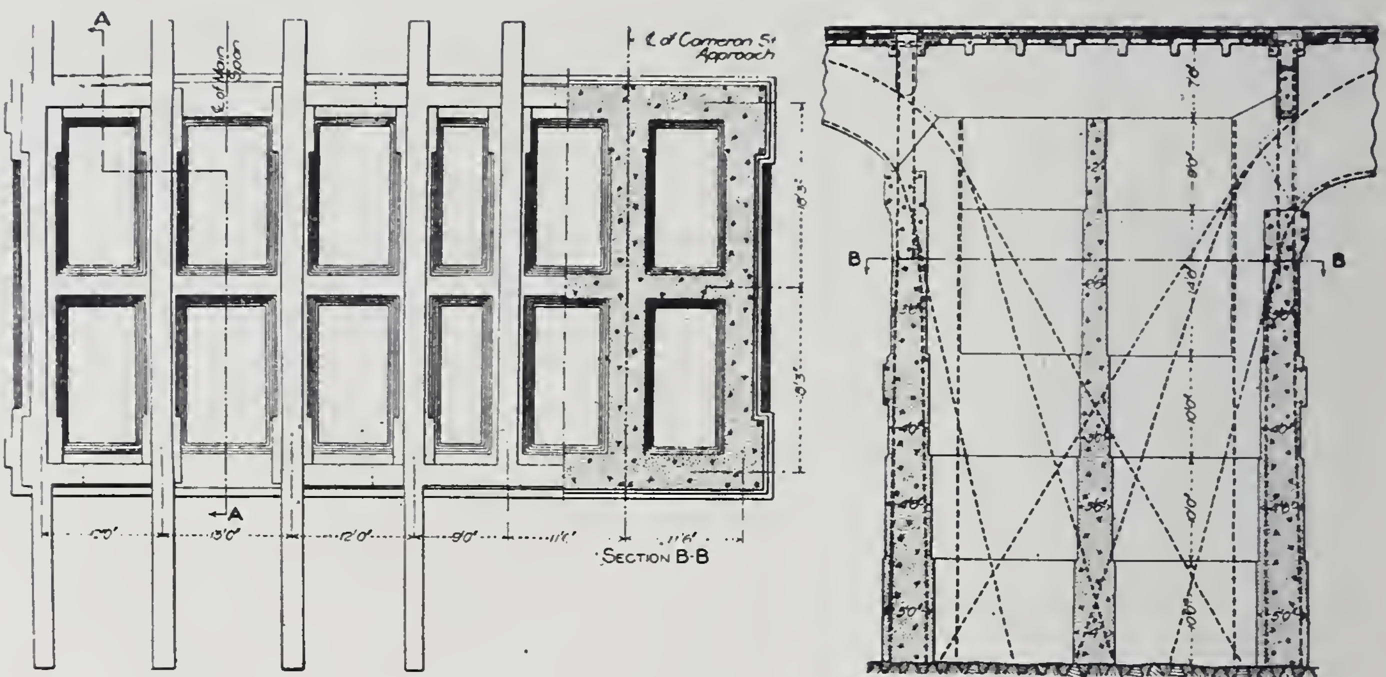

Fig. 3.—Abutment Pier.

face wall is 30 feet in height and not reinforced. Pockets were formed in the face wall to receive the arch ribs.

In the rib arch construction the abutment walls are built simply as retaining walls, the ribs being continued as buttresses along the line of pressure to solid foundation. These buttresses were built monolithic with the walls, terminating in skewbacks within the face wall, and contained reinforcing continuous with the arch rib reinforcement. The West and Cameron Street abutment design was similar. Tongue and groove vertical expansion joints were placed about every 30 feet in the side walls.

The abutment pier, about the middle of the bridge, is 41 x 82 feet square and 64 feet extreme height, containing about 3500 cubic yards

of concrete. It is of cellular construction and the only reinforcement is the continuation of the rib reinforcing through the buttress walls. The exterior and the buttress walls are 5 feet thick at the bottom and are offset to 2 feet thick at the top, inclosing twelve rectangular wells about 16 feet long by 6 and 8 feet wide. The exterior is paneled and molded to conform with the remainder of the superstructure.

When excavation was started for this pier, the impossibility of draining the entire area was apparent, and the excavations for the exterior walls were carried down first, a side at a time, and concrete placed to above the ground-water line, which process, when completed,

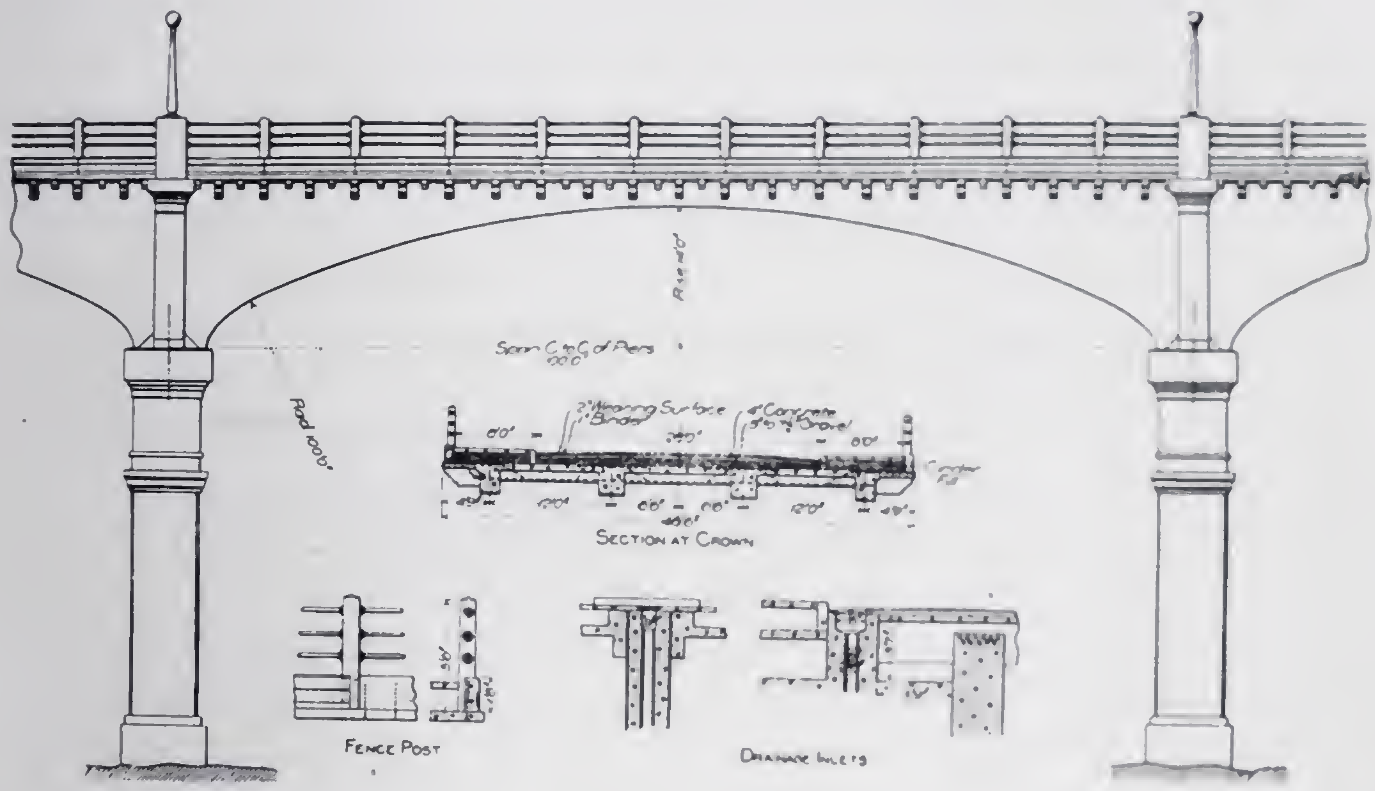

Fig. 4.—Main Bridge Span.

formed a concrete cofferdam, effectually excluding the water and allowing the interior work to be carried on without difficulty. This foundation concrete was placed during freezing weather, but a straw and tarpaulin covering proved a sufficient protection. Above grade the interior walls were built first with projecting keys to unite with the exterior walls. The forms were wired together and also braced with inclined shores to give stability for the great height. The exterior walls were granolithic faced and the entire pier hammer-dressed.

The piers of the eastern section were ready to receive the arches by July, 1908. These consist of four reinforced concrete ribs 3 feet deep at the crown, 17 feet deep at the skewbacks, and 12 feet apart on

centers. The two outer ribs are 24 inches thick and the two inner ribs 26 inches thick. The intrados is a curve of a radius equal to the span and a rise, on the 100-foot spans, of 14 feet. The ribs are combined with the spandrel walls, having a horizontal upper surface at the sub-grade of the roadway. Each rib is reinforced with 1-inch twisted bars continuous from out to out of supporting piers, one-half being located close to the surface of the intrados and the other half just below the extrados at the crown and diverging from the lower bars, passing over the skewbacks 11 feet apart. In addition, there was the line of bars in the top of each rib, giving the cantilever action, which required 14 square inches of steel over the pier in each rib for a 100-foot span. As the weight of a 100-foot span exceeded 1,000,000 lbs., no special provision was made for wind stresses, impact, or vibration, but to avoid long, unbraced compression members, the lower edges of the arch ribs are connected at the quarter points by horizontal slabs 10 feet wide and 6 inches thick.

A variation of 5 inches in the length of the bridge was calculated as the result of temperature changes, and allowance for it was made by expansion joints over the center of each pier. A corrugated break was made between the abutting ribs for a height of 7 feet over the skewbacks, and there widened to 2 feet and extended to the bridge deck. This pocket allowed access to the cantilever reinforcing bars and was sealed at the roadway sub-grade by concrete slabs.

The deck consists of a continuous slab of reinforced concrete, 8 inches thick in the central portion of the span and 6 inches thick at the ends, reinforced longitudinally with ½-inch twisted bars 9 inches apart in both the upper and lower surfaces. The slab is supported by transverse floor beams 19 inches deep and 9 inches wide, spaced 4 feet 6 inches on centers and reinforced with three ¾-inch twisted bars. The roadway slab cantilevers 4 feet beyond the outside ribs and is strengthened by ornamental brackets. The ribs, deck, beams, and brackets were built monolithic in day's-work sections the full width of the bridge, finished against radial bulkheads. All arch concrete was a 1 : 2 : 4 mixture with the sand item composed of one part sand and one part stone dust. A 100-foot span contained 333 cubic yards.

The specifications and design of the bridge required that the arches should be erected as balanced cantilevers. The original intention was to use the usual timber centering and preliminary studies were made. The method of construction required that three complete spans of centering should be provided in order that work might proceed with-

out interruption. This would have required 400,000 feet B. M. in the trestles and 42,000 feet B. M. for lagging and deck forms. A conservative estimate of this in place the first time was $22,000, and it is doubtful whether three times this quantity of lumber would have finished the bridge. The previous excavations had shown that it would be necessary to pile in many places to obtain a satisfactory foundation for the bents, but the impossibility of using bents across the railroad property made a new departure imperative and investigations were started along the line of steel trusses.

The conditions to be met by the centers were: they should carry, in addition to their own weight, a 100-foot span of bridge weighing 1,000,000 lbs., without appreciable deflection; they should have no intermediate supports; they should be adjustable in length to spans varying from 50 feet to 100 feet and in width for ribs varying from 22 inches to 26 inches; they should be arched to provide clearance over the railroads, but must not deliver any thrust to the piers; they must fit skew as well as regular arches; they should be light enough in their component parts to permit moving from place to place; and should be cheap enough to compete with timber construction.

All truss designs proved too expensive, and plate girders were tried. These too were excessive in both cost and deflection until advantage was taken of the method of arch construction and they were made into cantilevers balanced over the piers. This brought the cost very near to that of timber work, but the only way to make them actually economical was to dispense with some of the form work, and this was accomplished by splitting the girders longitudinally through the center of the web plate, moving the two halves apart the thickness of a rib, laying a floor within them on the line of the arch, and molding the concrete within the girders and against the web plates. This reduced the form work to the deck lagging only, and this was carried on the top flanges of the girders. The variation in the length of the spans was provided for by shortening the cantilevers and suspending a central girder between them, from which sections were cut to suit the span under construction.

Then came the question of providing supports for the end reactions of 565,000 lbs. It was necessary that these should be supported directly from bed rock, and there were the bridge piers already provided and proof against settlement. There was no footing on the piers suitable for the purpose, but the designer had left several openings through the curtain walls. Through these openings were passed beam

girders overhanging each side of the pier, and a beam girder along the face of the pier was suspended by bolts from these cantilevered beams, forming an adjustable footing for the centers.

The girder forms were proportioned for the heaviest rib of 26 inch thickness and 100 feet span. This rib, with its area of deck, weighed 300,000 lbs. The steel necessary to support this was estimated at 34,000 lbs. and the wood deck forms were approximated at 22,000 lbs., giving a total weight to be supported of 356,000 lbs. Subsequent calculations raised this to 380,000 lbs., making a reaction at each bearing point of 190,000 lbs. As construction was to be monolithic and by day's work finished against radial bulkheads, an assumption was made that 50 cubic yards could be placed per day, and the arch was divided into 14 spaces containing approximately 25 cubic yards each. As the load must be balanced over the pier, this gave 50 cubic yards as the day's work. These fourteen spaces gave a series of load points of 30,000 lbs. each, on which calculations were based.

There were three conditions of loading during construction. First, on leaving an abutment it was necessary to apply the complete load when one side only was a cantilever and the remainder a supported beam. This gave the maximum stress at the center of the span of 243,000 lbs. As the deflection here would have been excessive and the girder was not braced against buckling, a light bent was provided with a bearing $\frac{1}{8}$ inch below the girder in order to allow that deflection under load and obviate any danger of splitting.

Case two, which occurred in every span, where one side was a cantilever and the remainder a supported beam and the cantilevered side loaded to the center of the span. This gave maximum stresses at the reaction point, the cantilever flanges and ties, and the connection to the middle girder. The reaction at the loaded end was 189,000 lbs., the stresses in the cantilever flanges and ties was 303,000 lbs., and the connection to the middle girder was 193,000 lbs.

The third case, which also occurred in every span, was a complete load with both ends acting as cantilevers. This gave stresses below those of cases one and two, and was useful only for calculating deflections. Case two gave the maximum deflection of $\frac{9}{16}$ inch at the outer end of the untied cantilever, but as this point was raised when the cantilever was tied, the deflection became a mean between this and case three, or about $\frac{3}{8}$ inch. This was shown to be correct by actual performance, the deflections varying from $\frac{1}{4}$ inch to $\frac{3}{8}$ inch, and in only one case was this exceeded by a maximum of $\frac{1}{2}$ inch.

As the concrete arch itself was to be constructed as a self-supporting cantilever, there was no doubt that the centers would be relieved of a large amount of the load by their own deflection. What this relief would amount to could not be positively figured, but no hesitation was felt in placing a unit stress of 32,000 lbs. per square inch on the steel for purposes of calculation.

The cantilevers were made 22 feet 6 inches long, 4 feet deep at the outer end, and 12 feet deep at the point of support. The top and bottom flange angles were $6 \times 6 \times \frac{9}{16}$ inches and stiffeners were placed about every 4 feet. The web plates were $\frac{5}{16}$ inch thick and $\frac{7}{8}$ inch rivets, countersunk in the webs, were used throughout. The support was a rocker bearing made from two $6 \times 3\frac{1}{2} \times \frac{3}{4}$ inch angles.

The girders were 4 feet deep and 45 feet long with $6 \times 6 \times \frac{7}{16}$ inch flange angles and $\frac{5}{16}$-inch web plates. As the varying lengths of spans required these girders to be cut thirteen times, the stiffeners were spaced to suit these cuts and the flange angles were drilled at the shop for all these connections. The only field work necessary to shorten the girders was to cut the flange angles with a hack saw and chisel down the web along the face of a stiffener.

The bottom flanges of both cantilevers and girders were connected by stay plates at intervals of about three feet. These plates were drilled in multiple to suit the varying widths of ribs.

The adjustable flooring for the arch consisted of $\frac{7}{8}$-inch tongued and grooved lagging on three lines of 3×8 inch yellow pine joist, cut to radius and supported as follows: $5 \times 3 \times \frac{3}{8}$ inch angles were bolted on each side through the stiffeners, in a vertical position. The 5-inch leg was outstanding and was drilled for two series of 1-inch bolts. Connecting these angles were two $5 \times 3 \times \frac{5}{16}$ inch angles with the 3-inch leg forming a shelf to receive the scarf boards. Adjustment to the different widths of ribs was secured by using alternate series of holes in the outstanding angles.

The top flanges were kept in alignment by 1-inch bolts and pipe separators spaced about every 4 feet and molded into the ribs. To allow for deflection of the centers without putting a load on the portion of the arch already in place, these pipe separators were made 2 inches inside diameter, allowing the bolts and centers a play of 1 inch free of the concrete. No further provision was made against buckling of the top flanges. The pipe separators were made with ring ends and the main body of the pipe was allowed to remain embedded in the concrete.

Connection between the cantilevers and girders was made by $5\frac{1}{2}$ x 1 x 4 feet 6 inch splice plates on the flanges, secured by twenty-four bolts 1 inch diameter. To avoid jamming, thin wedges were inserted between the abutting ends of the flanges, which, upon removal, allowed the girder to swing free.

To comply with the method of construction, required that three complete spans of centering should be provided, and in order that work

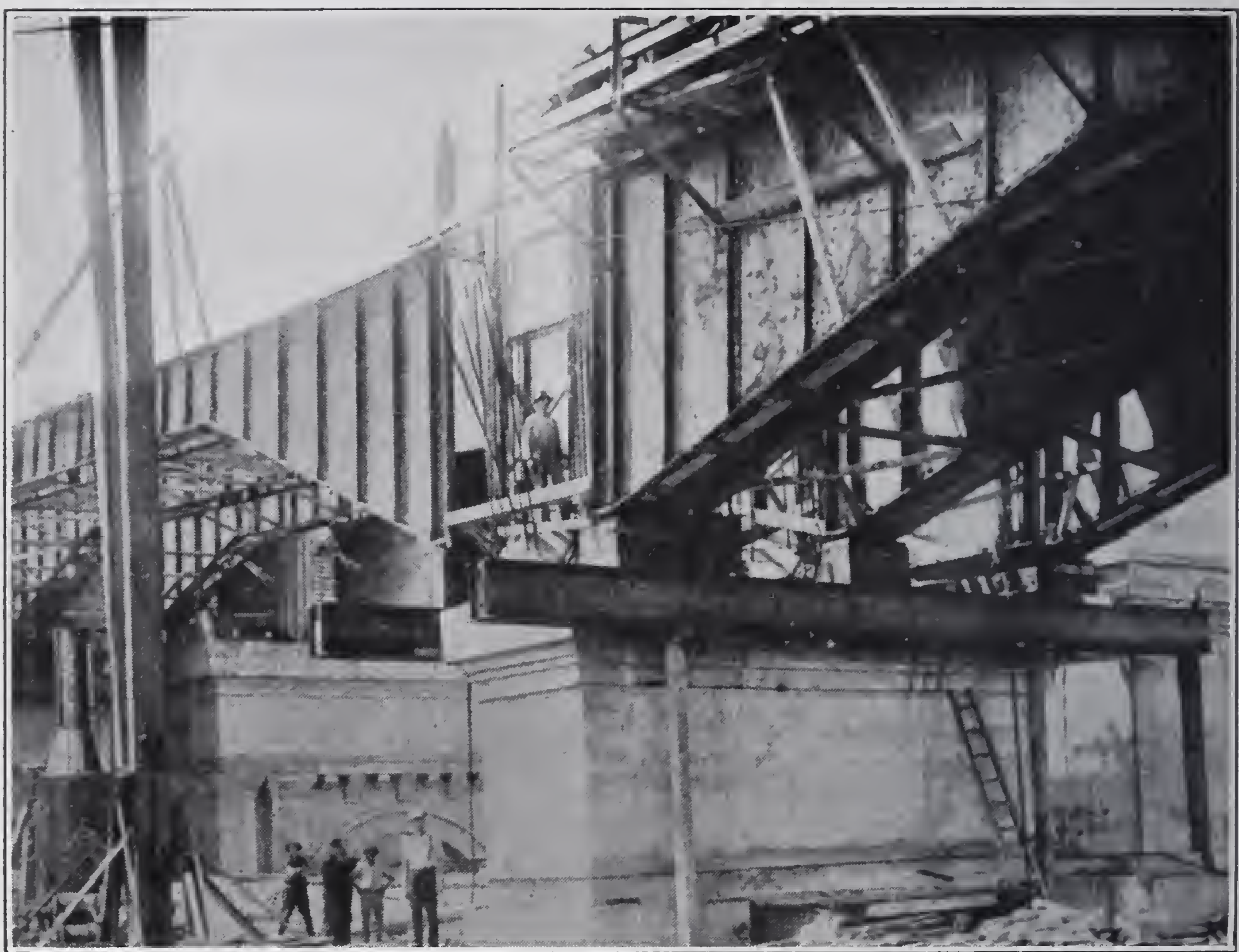

Fig. 5.—Steel Centers.

should not be delayed it was necessary that one span should be shifted while concrete was being placed in the other two. This meant that the cantilever must be removed from one side of the pier without allowing the tie to its mate on the other side to be slackened. On the top flanges of the cantilevers were riveted sections of 50-lb. T rail milled down to form a latch. Across these latches and through the concrete rib was placed a latch bar of two 8-inch channels with the flanges turned in. These channels were separated $\frac{1}{8}$ inch by wood blocking to allow for collapsing them prior to removal from the concrete. The

outer ends of these bars were connected across the pier by two $3\frac{1}{2}$-inch diameter bolts. Thus, when a cantilever support was lowered, the latch slid past the bar and released the cantilever tie, leaving the bar bedded in the concrete and supporting the pull of 300,000 lbs. from the cantilever still in place. The bottom thrust was taken directly through the concrete rib by a stepped bearing of wood blocking backed up by angles and plates connected to the bottom flanges of the cantilevers. The protruding steps left on the ribs were hammer-dressed away after the centers were lowered.

The overhang of the bridge deck was carried by light brackets of $3 \times 3 \times \frac{1}{4}$ inch angles, projecting 5 feet beyond the rib and supporting a $6 \times 4 \times \frac{3}{8}$ inch longitudinal angle which held the outer ends of the bracket forms. These supporting brackets were bolted to the stiffeners of the outside ribs and were spaced about every 8 feet.

The cantilevers weighed complete 5.47 tons each and the 45-foot girders 5.51 tons, making a total per rib of 16.47 tons and a total per span of 65.88 tons. This was increased 2.5 tons by the sway rods and miscellaneous pieces, making 68 tons per span and a total for three spans of 204 tons.

The outer ribs being placed at the edge of the pier allowed no chance of support at that point, and the nearest opening through the curtain wall being several feet inside of the rib, made it necessary that the support for the outside rib be a cantilever with an overhang of 3 feet. The next rib, 12 feet distant and 9 feet inside the point of support for the cantilever, was 3 feet away from another point of support. The arrangement was similar for the other half of the pier, making a combination of a continuous beam and a cantilever, 40 feet in length. The load of the outer rib was 170,000 lbs. and the inner rib 190,000 lbs., giving a maximum reaction at the support nearest the cantilever of 255,000 lbs. This required the supporting member, stressed to 20,000 lbs. per square inch, to be a beam girder of two 24-inch 80-lb. I beams.

These girders were suspended by four bolts 5 inches diameter, with double nuts top and bottom, bearing on $18 \times 18 \times 1\frac{1}{2}$ inch steel plates. The heaviest load on a single bolt was 255,000 lbs., giving a tensile stress of 16,000 lbs. per square inch.

The bolts were carried by four beam girders of two 24-inch 100-lb. I beams crossing the top of the pier through the openings in the curtain walls and resting on plates $18 \times 21 \times 1$ inches to distribute the load to the concrete. These girders were also cantilevered, and the load being

applied equally both sides of a pier kept them in balance. The necessity for removing the centers from one span before the adjoining one was completed upset this balance and required that the overload should be taken by a tie to the pier concrete. This was supplied by $3\frac{1}{2}$ inch diameter bolts with nuts engaging $12 \times 18 \times 1\frac{1}{2}$ inch plates embedded four feet in the pier cap. After the centers were removed, the bolts were screwed out, leaving the nut and plate embedded.

During part of the construction it was necessary that the cantilever foot should be carried at varying heights above the supporting girder, and wood blocking, consisting of three pieces of 12 x 18 inch yellow pine capped with an 18 x 2 x 38 inch steel plate, was utilized. This was secured to the girder by two 1-inch bolts passing up between the blocks and with their heads countersunk in the plate.

The ribs were not the same distance apart throughout the bridge and on the curved portion they were not even parallel. Steel sway bracing could not be used to fit all conditions and timber sways were made into panels and spaced about 15 feet apart. Turnbuckle rods were used at each sway panel to tie the ribs together and hold them to the panels. Crossed turnbuckle rods connected the cantilevers together on the bottom flanges to prevent side deflection and kicks.

Ninety-four tons of steel were required for the supports, making a total of 300 tons required for the entire construction.

The contract for the steel was placed with the Pennsylvania Steel Co. on May 1, 1908, and it was delivered on the ground by June 30, 1908, at a total cost of $16,000.

An attempt was made to obtain a comparison of cost between the steel and timber centering, and a 40-foot span adjacent to the central abutment pier was constructed of timber. The result was not of much value as a comparison, but was very useful in convincing the adherents of timber construction that it was almost impracticable to build this bridge in such a manner.

The Cameron Street approach, with its start at grade and gradual rise to the bridge level, offered an ideal place to try out the new construction, and erection was started here on July 6, 1908. The approach having but three ribs to the span, allowed the entire four spans to be erected at once. To save time, the rib sections were raised separately and assembled in the air, but were not disassembled again until the completion of the last arch. The approach piers had been built before the centers were designed, and the anchor plates and nuts were not embedded in the pier caps, necessitating the girders crossing

the piers being held down by bolts passing down the face of the pier cap and engaging other beam girders crossing beneath the cap, forming a steel strap inclosing the entire cap beam.

The deck forms were constructed in the sawmill while the steel was being erected and were placed as soon as a span was completed. They consisted of a series of boxes, placed 9 inches apart, to form troughs for the floor beams, and were supported on 2 x 12 inch joist which rested on the top flanges of the steel forms. The sides were sloped to

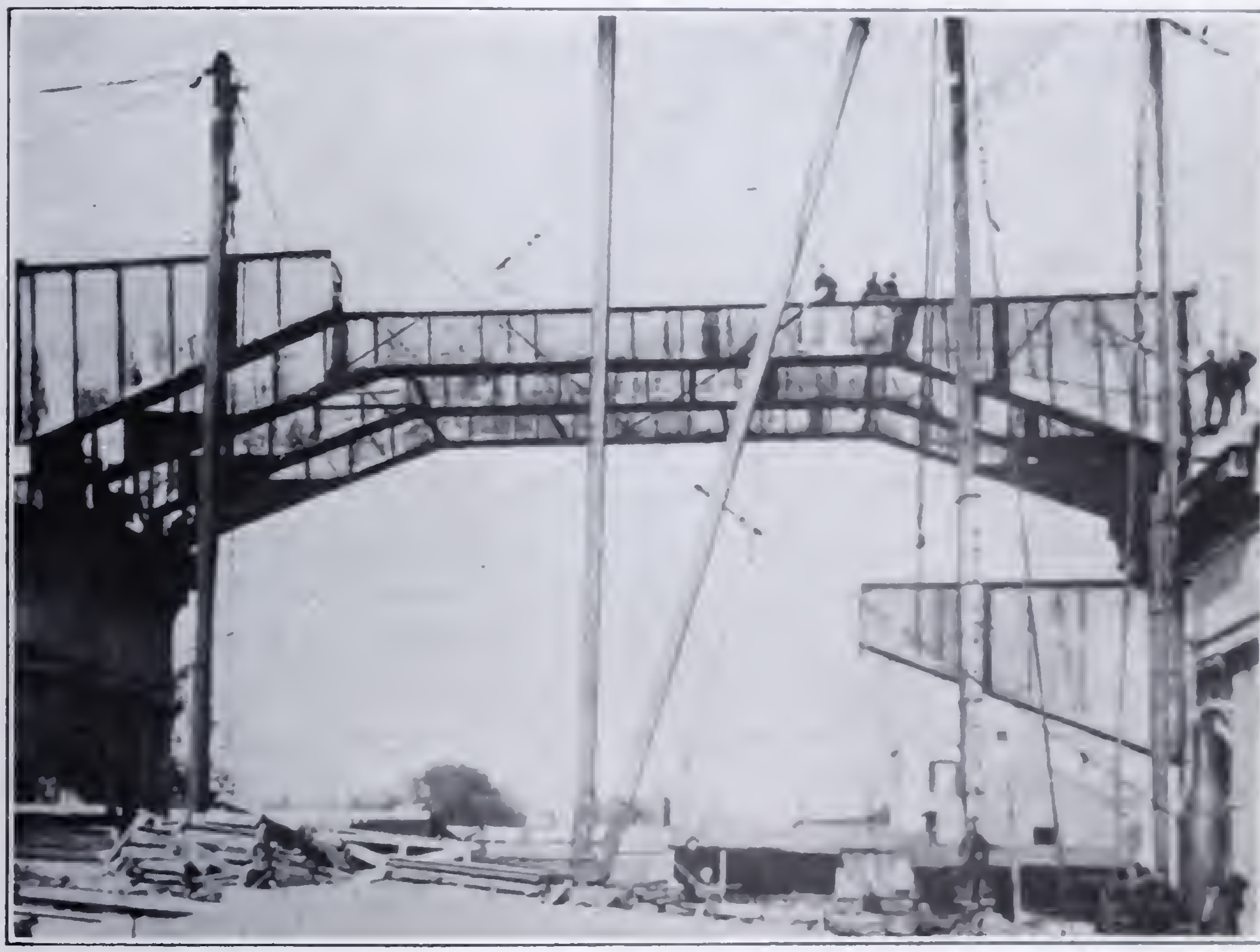

Fig. 6.—Erecting Centers.

give a draw all around and the edge strip around the top was loosely tacked to aid in removal.

The spaces over the piers not covered by the steel were closed in with wood between the cantilever ends the full height of the ribs, the reinforcement placed, and arch concrete started August 1, 1908. Concrete was all placed and the first centers removed by September 15th, and erection was under way on the main bridge. The curtain walls were molded immediately following the completion of the arch and previous to lowering the forms, as the removal of the steel would

have left no sway bracing between the ribs. This work was completed and all forms removed from the approach by September 25th.

The forms for the large brackets over the piers were made in one piece and raised to position as soon as the wooden rib form was removed. The compression braces at the quarter points of the arch had been provided for by molding into the ribs a 6 x 6 inch timber carrying steel stubs. This, when removed, left in the rib a 6-inch socket with projecting stubs to receive the slab. Through the pipe separators, left in the rib by the centers, were passed steel bars from which the forms were suspended for molding the slabs. These bars also provided support for the staging from which the hammer-dressing was done.

On the main bridge the supporting beams were placed first, anchored to the pier, and the footing blocks adjusted to level. The cantilevers were then raised complete by two gin poles, one at each end, and placed on their seats. The outer ends were held in position by the gin poles until the middle girder was raised and bolted fast. The wedges were then placed in the joint, the shear bolts inserted, and the end stiffener angles drawn together. The gin poles were removed to the next span, the sway frames placed and the ribs drawn into alignment with the turnbuckle rods. The rib flooring was placed to a template drawing in each section previous to erecting, and the steel was ready for the deck forms as soon as the connections were made. The tie bolts connecting the latch bars were drawn tight while jacks placed between the abutting cantilevers at the point of support raised the center of the span, thus insuring true cantilevers without arch action. The time consumed by this method of erection was four days for a 100-foot span.

The deck forms were placed from the piers outward and concrete was started two days behind the carpenters. The form work occupied eight days and the concrete keystone was usually in place on the eleventh day. The reinforcement was very heavy, and the men who had to spade concrete at the bottom of a rib 2 feet wide and 17 feet deep had no easy task to work their way through the bars. It also complicated the erection of the bulkheads for each day's work. These consisted of two 6 x 6 inch timbers in each rib, set to a radial line and holding a series of stop boards which were placed as the concrete was laid. Blocks on the stop boards formed 2-inch depressions in the face of the concrete to serve as shear keys for the next section.

Concrete was mixed on the ground and raised to the deck by the 90-foot derricks, where it was deposited in portable bins of about 2 cubic yards capacity. From these, it was drawn off into two wheeled

carts holding 5 cubic feet, wheeled where required, and dumped into place. It was now seen that the estimate of 50 cubic yards per day was too low, as double this quantity could have been placed, but it was not thought advisable to increase the size of the voussoir sections beyond eleven spaces. As the success of the construction depended on the bond of the reinforcement for the cantilever effect, tests were made of each day's work by bedding $\frac{3}{8}$-inch bars in the concrete to a depth of 6 inches and pulling them at intervals. When they indicated a

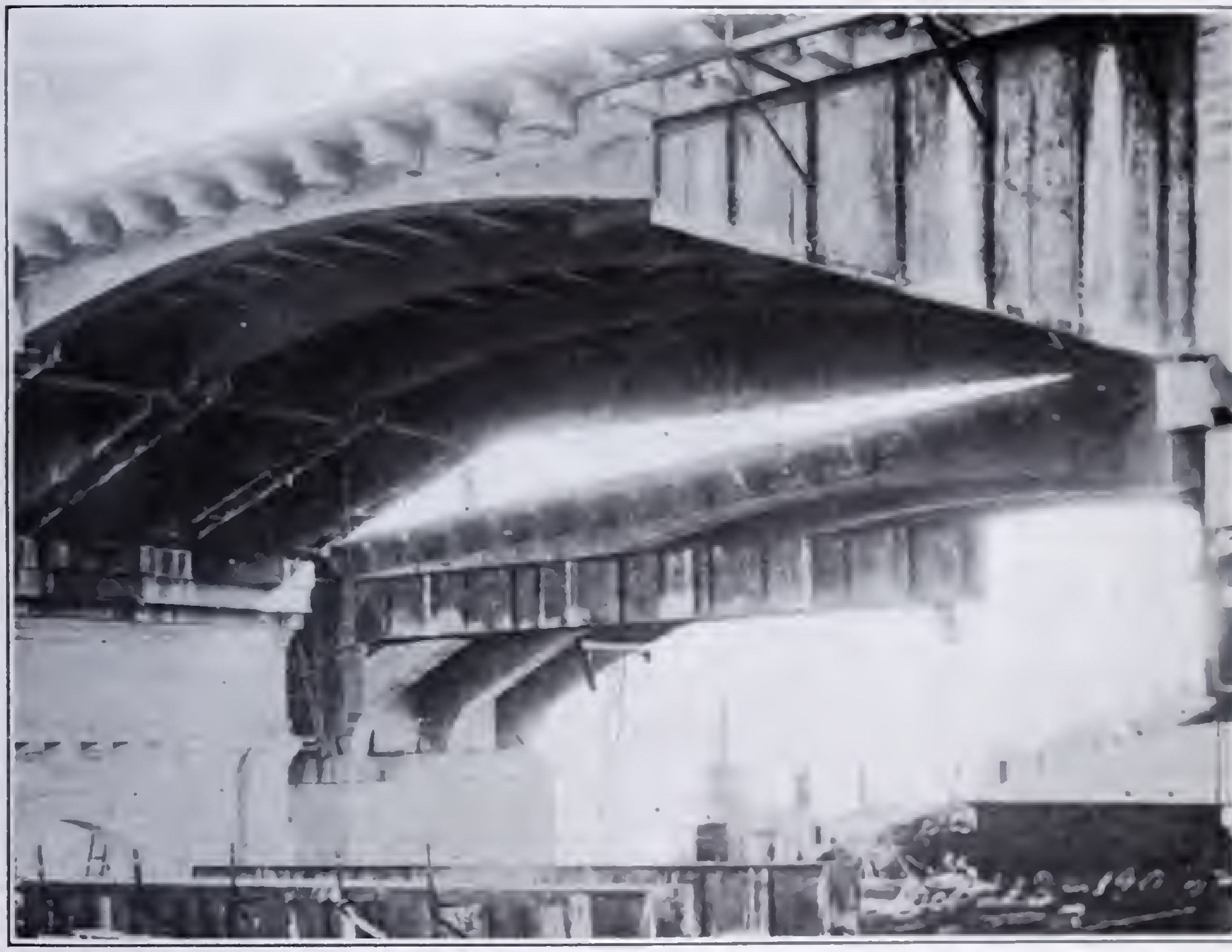

Fig. 7.—Lowering Centers.

resistance in pounds per square inch of surface sufficient for the main reinforcement to support the weight of another section, the work was proceeded with.

The wood deck forms were stripped two days behind the placing of concrete sections and the centers were lowered three days after the keystone was placed. Steel cables were attached to each of the four corners of a girder and led upward, through openings left in the bridge deck, to geared winches resting on the concrete deck. Then the shear

bolts and wedges were removed, the tie plates disconnected, and the girders lowered to the ground.

The cables were then attached to the cantilevers, the supporting girder lowered by slacking off the nuts on the 5-inch bolts until the latches disengaged from the bars, the cantilevers skidded outward past the girder and lowered to the ground. Four days were occupied by this work on the 100-foot spans. On the eastern section of the bridge, with this method of working, 700 linear feet of deck was built in ninety-nine days, including Sundays and rainy days, an average rate of prog-

Fig. 8.—Cameron Street Approach.

ress of 100 feet in fourteen days, the work being started on September 20th and completed December 27th. Arch concrete was proceeded with during freezing weather by covering the deck with canvas and laying steam-pipes inside the steel centers. The overhang was protected by canvas curtains and coke ovens were suspended from the sidewalk brackets. No difficulty was experienced in maintaining a temperature in excess of 40° F.

When the deck was completed from the east abutment to the abutment pier, the reinforcing bars giving the cantilever action were cut

over the piers, allowing the spans to become arches. A man with a hack saw was stationed at each arch rib over the first pier and one reinforcing bar was cut simultaneously in each rib. The men then moved to the next pier, cutting one bar, and continued thus to the last pier. This operation was repeated until all the bars were cut. There was no perceptible elongation as the acting cross-section was reduced, but the last bars snapped when cut partly through, although they did not separate much. The deflection at the center of the span

Fig. 9.—Stairway at Tenth Street.

was very slight; in fact, was within the possible error of measurement, but in one case a drop of $\frac{1}{8}$ inch was observed. Possibly no harm would have been done to the structure if these bars had been left uncut, as the amount of steel in the pits free of the concrete could have elongated under the temperature stresses, but it was thought unwise to leave the structure a combination of indeterminate stresses due to both cantilever and arch action.

On the western section of the bridge the railroads became a helper instead of a trouble-maker. The ribs were assembled complete on

flat cars, hauled to the desired location, and raised bodily into place by the wrecking derrick of the railroad. A complete span was erected in this way in two hours' derrick work, traffic was not interfered with, and all tracks were kept open as required. The last arch was completed on June 5, 1909, eleven months after the first arch concrete was placed.

Each of the 300 tons of steel in the centers was shifted seven times, a total of 2100 tons of steel erected and removed again, and the concrete supported by them was 8000 cubic yards. The total amount of lumber used in the entire construction was 800,000 feet B. M., giving some idea of the quantity which would have been required if the steel centers had not been used.

The bridge railing consisted of concrete posts 10 inches square and 5 feet 6 inches high carrying three lines of wrought pipe. Holes for $\frac{3}{4}$-inch bolts were cored in the posts on the line of the pipe and ornamental sockets placed on each side and secured by a bolt connection through the posts. The posts were spaced 9 feet on centers and anchored in place by the fascia curb being built around their bases. The fascia was 20 inches high, with a paneled exterior surface, and was secured by quills of $\frac{3}{8}$-inch steel, which were placed every 18 inches when the bridge deck was molded. Expansion joints were provided at each hand-rail post and alternate sections were molded in succession. The roadway curbs were 18 inches high and 6 inches thick, located 8 feet inside the line of railing and simply rested on the deck. The curb and fascia inclosed a cinder fill 14 inches deep, containing electric conduits, and carrying a 4-inch granolithic sidewalk. The roadway had a cushion of gravel 6 inches thick carrying the asphalt paving on a 4-inch concrete base. At each pier, and mounted on the large pier brackets, were concrete posts 6 feet high and 3 x 2 feet square, which formed a base for the lamp-posts.

These were also of concrete. Cluster lights were placed at each abutment entrance and at the junction of the Cameron Street approach with the main bridge, the intermediate lights being single.

At Tenth Street and at the east abutment, concrete stairways were built from grade to the bridge deck, supported on concrete brackets molded onto the piers.

The asphalt paving was started on June 15, and completed July 11, 1909, and the completed bridge was thrown open to travel August 6, 1909—just two years from the time the old bridge was closed.

DISCUSSION.

WM. EASBY, JR.—In regard to a concrete structure such as this is, what will be the effect of time and the elements upon the sharpness of the lines? It has occurred to me that the bush-hammer finish on the surface would lessen somewhat the durability of the surface.

H. H. QUIMBY.—Answering the last question first, the removal of the film of concrete may increase the durability of the surface, because the film that segregates against the forms of concrete is subject to cracking, and if it be removed then there would seem to be nothing to start the cracking. I have yet to see a hair crack in a surface that has been made either by washing while friable or by dressing it with a tool after it has hardened.

It is likely that time will soften the lines. The best concrete that has ever been made is not equal to good hard stone, and the corners will probably wear off in the weather. I have more hopes now of the durability of sharp corners than I had some time ago, because I have recently examined some sharp corners of concrete that have stood much better than I expected them to. If the surface is fairly rich in cement, the sharp corners will last a long time.

The structure described in the paper is a very creditable piece of work, both to the engineer who designed it and to the contractor's engineers who designed the method of erection. It was apparently perfectly successful and economical. The cost of the bridge seems to be very low. The total cost as given appears to be only about $2.40 per square foot.

I was particularly interested in two features of the work, very intimately related; they are the method of construction by means of cantilever forms, and the cantilever reinforcement embedded in the concrete over the piers. The bars were cut after the arch ribs were keyed, and the reason given was that it was not thought wise to have a condition of indeterminate stresses. It does seem, on general principles, that we should know where and what our stresses are, but, it seems also that those bars furnish certainly some element of additional stiffness to the structure, and I would have waited to see what the effect on the bars would be of changes in temperature. If the highest temperature in summer would not relieve the bars of tensile stress and put compression in them, I would let them go without cutting them. I visited the work while it was under way and observed such of the bars as had been cut; they had evidently snapped under the tension that was on them, and I think some of them snapped before the saw got through, indicating considerable stress in them. The saw cut was not very wide, and the amount of retraction therefore was not large, due probably to the shortness of the length exposed. The bars still uncut were as tight as fiddle-strings. I think it was in the spring I was there; probably at the time of middle temperature. I feel curious to know what would happen to those bars if they were permitted to remain there during the season of high temperatures.

We are now building in this city a reinforced concrete bridge combining the properties of the arch and the cantilever. The reinforcement consists of structural shapes and angles. The point at which those bars were cut in the Harrisburg bridge is the point of maximum tension in our bridge. We expect to get with the combination of arch and cantilever, in spite of the indeterminate stresses that may be there, considerable stiffness.

Mr. Allen.—As to the time of cutting, the weather was very cold. It was in December. There were no ill effects from having been tied together up to that time.

John C. Trautwine, Jr.—Mr. Easby's question, as to the wear of corners in concrete work, reminds me of the appearance of the pillars under the hand-railing of Mr. Quimby's monumental Walnut Lane bridge. These pillars are of square cross-section; and the finishing method employed, in which the cement paste, at the surface, is washed out, leaves these corners with an unfortunately ragged appearance. It has been suggested that the weather will eventually round off all square corners in concrete work. Would it not be better to round off these corners in the mold, and thus save the weather the trouble? In drive-ways, entering warehouses, the corners are often set with rounded bricks, and the effect is more pleasing than where they are left sharp and the rounding is subsequently done by contact with abrading wagon wheels.

Mr. Quimby.—I would like to say another word in reference to sharp corners. We are continually striving for the unobtainable, and if we were not, we would be satisfied with something less. The beauty of that work is, in my opinion, in those sharp edges. We cannot make ornamental edges that will look pretty. Concrete work was originally made with rounded edges, and they are out of shape and look very miserable to-day. The beauty of the work is in the sharpened edges. It is hard to keep the workmen off those edges, and the workman who washes it is the worst offender. It is hard to prevent the work-men washing off the corners; it was done in places where it should not and need not have been done.

ABSTRACT OF MINUTES OF THE CLUB.

Business Meeting, September 18, 1909.—The meeting was called to order by the President at 8.40 P. M., with 106 members and visitors in attendance. The minutes of the Business Meeting of June 5th were approved as printed in abstract.

A letter was read from the Engineers' Club of New York, extending the privileges of the Club, exclusive of rooms, to members of this Club during the Hudson-Fulton Memorial Celebration.

A letter was read from H. W. Spangler, resigning the Chairmanship of the Committee on Nominations, on account of ill health. Upon motion of Mr. Riegner, Mr. Thomas McBride was appointed Chairman of this Committee. The new Committee on Nominations, consisting of Thomas McBride, Chairman; E. M. Nichols, William C. Kerr, H. F. Sanville and St. George H. Cooke, was then approved.

The following amendment to the By-Laws and statement from the Board of Directors was presented:

We, the undersigned, propose that Section 2, Article VI, of the By-Laws be amended to read as follows:

"The annual dues of all Resident Active and Associate Members shall be $35.00; of Resident Junior Members, $12.50, of which $2.50 shall be set apart for the use of the Junior Section, payable on its order; of Non-Resident Active and Associate Members, $12.50, and of Non-Resident Junior Members, $5.00. One-half of each of these membership dues shall be payable in advance on the first day of January and July."

(Signed) W. P. Dallett, H. E. Ehlers, W. P. Taylor, Charles F. Mebus, William S. Twining, George T. Gwilliam, Washington Devereux, A. C. Wood, Henry H. Quimby, J. O. Clarke.

This amendment to the By-Laws was proposed on the recommendation of the Board of Directors, and will come up for discussion at the stated meeting of the Club on October 14th. The Secretary made a statement giving the reasons of the Board for this recommendation.

Mr. H. H. Quimby, Active Member, presented a paper on "The Substructure of the Passyunk Avenue Bridge," which was discussed by Messrs. George S. Webster, C. M. Mills, J. W. Silliman, W. C. Furber, E. M. Nichols and others.

Upon motion, the meeting adjourned at 10.40 P. M.

Business Meeting, October 2, 1909.—The meeting was called to order by the President at 8.50 P. M., with 88 members and visitors in attendance. The minutes of the Business Meeting of September 18th were approved as printed in abstract.

Following a report of the Tellers, the President declared that the following had been elected to membership in the Club: To Active Membership, Wyllys E. Dowd, Jr., Victor J. Goetz, F. Justice Grugan, John E. Hires, Millard P.

Osbourn, Ernest A. Sterling, G. Wise; to Associate Membership, A. W. Atkinson, Llewellyn R. Duffield, Raymond W. Hilles, E. T. Wilkinson; to Junior Membership, Lewis H. Haupt, Louis J. F. Moore, Haviland H. Platt, Joseph W. Ward, Harry R. Wilkinson.

Mr. H. Clyde Snook, Active Member, presented the paper of the evening, entitled "The Testing of Sheet Steel for Magnetic Circuits," which was discussed by Messrs. Hering, Bonine, Leeds and others.

Upon motion, the meeting adjourned at 9.40 P. M.

Business Meeting of the Club, held Saturday, October 16, 1909.—The meeting was called to order at 8.30 P. M., with 100 members and visitors in attendance. The minutes of the Business Meeting of October 2d were approved as printed in abstract.

The amendment to the By-Laws, proposed on September 18th, raising the annual dues of Resident, Active, and Associate Members from $25.00 to $35.00 was brought up, and upon motion, was ordered to be sent to the membership for letter ballot.

Messrs. John E. Allen and Benjamin G. Love presented the paper of the evening, entitled "The Mulberry Street Viaduct at Harrisburg, Pa.," which was discussed by Messrs. Wm. Easby, Jr., Henry H. Quimby, Walter Loring Webb, John C. Trautwine, Jr., and others.

Upon motion, the meeting adjourned at 10.50 P. M.

ABSTRACT OF MINUTES OF THE BOARD OF DIRECTORS.

Regular Meeting, September 9, 1909.—Present: President Dallett, Directors Twining, Christie, Cochrane, Develin, Hess, Gwilliam, Wood and the Secretary.

The President announced that the following had been appointed as a Committee to co-operate with the Committees of other engineering clubs in Pennsylvania to formulate a Code for the Licensing of Engineers: Dr. Edgar Marburg, Chairman, Mr. John Birkinbine, Mr. W. P. Taylor.

The Secretary reported that the Directory had been published, at an expense of $359.85; that the income from the advertisements had been $770.00, leaving a profit of $410.15, as against the profit last year of $240.00.

The Secretary read a report from the Treasurer, and, following this report, it was ordered that a new form of contract proposed by the accountants, C. W. Todd & Company, as in their letter of September 1st, be accepted; that delinquents to the amount of $2.00 on House charges should be posted on the bulletin board, and that a registered letter be sent to all members delinquent in dues on October 1st, calling attention to this fact, and requesting payment.

The President appointed Mr. James Christie an additional member of the Committee on Membership.

The question of requesting the contribution of matter for the publications from members, other than the regular papers read before the meetings, was discussed, and referred to the Committee on Publication, with power to act.

A letter from Mr. C. J. Steen, in relation to the condition of the library, was referred to the Committee on Library.

Mr. Twining, Chairman of the Committee on House, brought up the restaurant question, and after some discussion, it was ordered that the present contract be continued, if provision could be made for terminating it on two weeks' notice, at any time.

It was moved that an amendment, proposing an increase of dues of Resident, Active, and Associate Members be proposed, with the recommendation of the Board.

The resignations of Mr. George Wm. Moreton and Mr. Frederick Conlin were accepted as of December 31, 1909, and the resignation of Mr. E. Graves as of June 30, 1909.

Special Meeting, September 18, 1909.—Present: President Dallett, Vice-President Devereux, Directors Clarke, Quimby, Twining, Gwilliam, Mebus, Wood, the Secretary, and the Treasurer.

A new form of contract with the caterer, drawn up by the Chairman of the House Committee and the Secretary, terminating November 30, 1909, was read and approved.

A letter from Mr. Devereux, Chairman of the Committee on Library, asking for an appropriation of $500, was read and laid on the table.

A statement, drafted by the Secretary, stating the reasons for recommending the increase of dues, was read, and it was moved that this statement be read at the meeting of the Club on September 18th, at the time the amendment, raising the dues, was to be proposed.

It was ordered that the President and Treasurer be authorized to negotiate a loan to liquidate the indebtedness of the Club, in an amount not exceeding five thousand dollars, for four months.

It was ordered that all delinquents in House charges over three months be posted, and that delinquents in an amount over two dollars be posted in the regular manner stipulated by the House rules.

Regular Meeting, October 14, 1909.—Present: President Dallett, Vice-President Easby, Directors Clarke, Head, Christie, Cochrane, Develin, the Secretary, and the Treasurer.

On recommendation from the Treasurer, an account of $6.00 to the Viennot Advertising Agency, bankrupt, was ordered charged off.

The resignation of Mr. Schuyler V. V. Hoffman, Associate Member, was accepted as of October 14, 1909.

A Committee of the Board of Directors, consisting of W. P. Taylor, Chairman, H. P. Cochrane, R. G. Develin, and H. E. Ehlers was appointed, to arrange for giving a Club Smoker, to be held some time during the fall, and to be held without expense to the Club. This Committee was given power to appoint other special and general Committees for this purpose.

Special Meeting, October 25, 1909.—Present: President Dallett, Vice-President Easby, Directors Clarke, Head, Twining, Christie, Cochrane, Develin, Gwilliam, Hutchinson, and the Secretary.

A letter from Mr. Philip L. Spalding, tendering his resignation as Vice-President of the Club, was read, but action deferred until the next regular meeting.

The special business of the meeting, consisting of the formulation of action to assist in the passing of the amendment, increasing the dues, was considered, and after discussion, a circular letter, which was read and approved, was ordered to be issued to the voting membership, and to be sent under separate envelope at the same time the ballots were issued.

Mr. Christie spoke on the advisability of increasing the membership, and after discussion, the President, acting on authority of the Board given at the meeting of June 5, 1909, appointed the present Membership Committee of the Board as a special committee to organize a movement leading to an increase in membership, with power to increase their number, to appoint other committees, and to do whatever seemed expedient to secure the best results.